DIVISION 1100. EQUIPMENT

SECTION 1101. GENERAL EQUIPMENT

All equipment utilized in the removal of roadway surfaces or waterproofing membranes shall meet, and shall be operated in compliance with a visual emission limitation of 30 percent opacity or Ringleman 1 for a period not longer than one minute and for not more than four minutes in the aggregate in any 60 minute period.

1101.01 Rollers. No roller shall be used that has in any way been thrown out of its original balance by the application of attachments not approved by the Engineer. All bearings shall be tight.

(a) Pneumatic-Tired Rollers. The roller shall consist of not less than nine pneumatic tires revolving on two axles. The tires on the front and rear wheels shall be staggered so that they will cover the entire area over which the roller travels. Under working conditions, the roller shall develop a compression of not less than 225 lb/in. (40 N/mm) width of tire tread.

(b) Heavy Pneumatic-Tired Rollers. The roller shall have a gross weight (mass) of not less than 25 tons (23 metric tons) and shall consist of not less than four pneumatic-tired wheels revolving in one transverse line. The width of the roller shall be not less than 8 ft (2.4 m), and it shall be constructed in two or more sections in such a manner that each section is free to oscillate or move independently. Under working conditions, the roller shall develop a compression of not less than 650 lb/in. (114 N/mm) width of tire tread.

(c) Self-Propelled Pneumatic-Tired Roller. The roller shall be of the oscillating wheel type consisting of not less than seven pneumatic-tired wheels revolving on two axles, and capable of being ballasted to the weight (mass) required. The tires on the front and rear wheels shall be staggered so that the tire sidewalls will have a minimum overlap of 1/2 in. (13 mm). The roller shall provide for a smooth operation when starting, stopping or reversing direction.

The tires shall withstand inflation pressures between 60 and 120 psi (415 and 825 kPa). The roller shall be equipped with an adequate scraping or cleaning device on each tire to prevent the accumulation of material on the tires. When used for the compaction of hot-mix asphalt, the roller shall be equipped with a water system which will keep all tires uniformly wet to prevent material pickup.

The Contractor shall provide means for determining the weight (mass) of the roller as distributed on each wheel. Ballast shall be included in determining the weight (mass).

(d) Tamping Rollers. The roller shall have a minimum weight (mass) of 90 lb/in. (16 N/mm) width of drum, and each individual tamper shall develop a compression of not less than 100 psi (690 kPa) of its tamping face area. The width of the tamping roller shall be not less than 8 ft (2.4 m), and it shall be constructed in two or more sections in such a manner that each section is

free to oscillate or move independently. It shall be equipped with cleaning teeth at the rear.

(e) Steel Wheel Rollers. The roller shall be self-propelled and provide a smooth operation when starting, stopping, or reversing directions. The steering mechanism shall provide for positive control of the roller. Roller wheels shall be smooth and free from openings or projections which will mar the surface on which the roller is operated. Motor rollers shall be equipped with drip pans to contain oil, grease, or gasoline drips generated by the roller operation. The roller shall be provided with adjustable scrapers which shall be used when necessary to keep the surface of the wheels clean.

When used on a hot-mix asphalt surface, the roller shall be equipped with water tanks and sprinkling devices which shall be used to wet the wheels and prevent material pickup.

(1) Tandem Rollers. The Contractor shall provide means for determining the weight (mass) of the roller as distributed on each axle. Ballast shall be included in determining the weight (mass).

The rear wheel may be crowned at the rate of not more than 3/16 in. in 4 1/2 ft (5 mm in 1.4 m). The front wheel shall be divided into at least two sections and shall show no noticeable crown. The weight (mass) of the roller shall meet requirements of the specific item of work being constructed.

(2) Three-Wheel Rollers. The rear wheels of three-wheel rollers may be crowned at the rate of not more than 1/16 in. in 20 in. (2 mm in 500 mm) and shall be propelled with a differential gear. The front wheel shall be divided into at least two sections, shall show no noticeable crown, and shall overlap the compression area of each rear wheel by not less than 1 1/2 in. (38 mm). The weight (mass) of the roller shall meet requirements of the specific item of work being constructed.

(f) Trench Roller. The roller shall be self-propelled, and provide a smooth operation when starting, stopping or reversing directions. The width of the compaction roller shall be not less than 20 in. (500 mm). The diameter of the compaction roller shall be not less than 60 in. (1500 mm). The roller wheels shall be smooth and free from openings or projections which will mar the surface on which the roller is operated. Motor rollers shall be equipped with drip pans to contain oil, grease or gasoline generated by the roller operation. The roller shall be provided with adjustable scrapers which shall be used when necessary to keep the surface of the wheels clean.

When used on a hot-mix asphalt (HMA) surface, the roller shall be equipped with water tanks and sprinkling devices which shall be used to wet the wheels and prevent material pickup.

The weight (mass) of the roller shall meet requirements of the specific item of work being constructed. The Contractor shall provide means for determining the weight (mass) of the roller as distributed on the compression wheel. Ballast shall be included in determining the weight (mass).

The balance wheel of the roller shall be adjustable in height to provide the slope of the surface of the specific item of work being constructed.

(g) Vibratory Roller. The vibratory roller shall be self-propelled and provide a smooth operation when starting, stopping or reversing directions. The vibrating drum(s) amplitude and frequency shall be approximately the same in each direction and meet the following minimum requirements: drum diameter 48 in. (1200 mm), length of drum 66 in. (1650 mm), vibrators 1600 vibrations per minute (VPM), unit static force on vibrating drum(s) 125 lb/in. (22 N/mm), total applied force 325 lb/in. (57 N/mm), adjustable eccentrics, and reversible eccentrics on nondriven drum(s). The total applied force for various combinations of VPM and eccentric positions shall be shown on decals on the vibrating roller or on a chart maintained with the roller. The vibratory roller shall be equipped with water tanks and sprinkling devices, or other approved methods, which shall be used to wet the wheels to prevent material pickup.

A vibrating reed tachometer (hand type) shall be furnished with each vibratory roller. The vibrating reed tachometer shall have a range of 1000 to 4000 VPM. The vibrating reed tachometer shall have two rows of reeds, one ranging from 1000 to 2000 VPM and the other from 2000 to 4000 VPM.

1101.02 Disk Harrow. The disk harrow shall be the tandem type and shall meet the approval of the Engineer prior to its use.

1101.03 Mechanical Sweeper. The sweeper shall permit the revolutions of the broom to be adjusted in relation to its progression and permit the adjustment of the broom in relation to the surface being cleaned. It shall be supplied with sufficient extra or repair parts to prevent delay. The broom bristles shall be stiff enough to sweep clean without cutting into the surface. A broom with steel bristles will not be permitted.

1101.04 Reserved.

1101.05 Motor Grader. The motor grader shall be self-powered and equipped with an adjustable mold board. The cutting blade shall be straight and in good condition. There shall be a minimum of play in the blade operating mechanism.

1101.06 Rotary Speed Mixer. Rotary speed mixers shall be either the power takeoff or the self-powered type, equipped with a hydraulic lift. Worn scarifying and mixing parts shall be replaced and extra parts shall be available for replacement.

1101.07 Traveling Mixing Plant. All traveling mixing plants shall meet the approval of the Engineer. The plants shall be either the type which will pulverize the material to be treated and mix the material and cement with the proper amount of water without picking the materials up from the roadway, or the pugmill type which elevates the material into a pugmill for mixing. The plant shall be equipped with a device which will accurately control and measure the quantity of water used. Worn scarifying and mixing parts shall be replaced and extra parts shall be available for replacements.

1101.08 Seeding Equipment. Seeding equipment shall be according to the following.

(a) Disk. The disk shall meet the approval of the Engineer and have sound unbroken blades, which have a minimum diameter of 15 in. (375 mm). The disk shall be weighted, if necessary, to obtain the required tillage depth of 3 in. (75 mm).

(b) Slope Harrow. Slope harrows shall consist of a rolling weight (mass) attached by heavy chain to a tractor. The chain shall be of a suitable length, shall have picks welded to the links, and shall have a means of rotating the picks as the rolling weight (mass) is pulled in a direction parallel to the movement of the tractor.

(c) Hydraulic Seeder. When hydraulic seeders are used, the inoculant and seed required shall be applied in a single operation.

Hydraulic seeding equipment shall include a pump rated and operated at no less than 100 gal/min (375 L/min) and no less than 100 psi (690 kPa) pressure. The tank shall have a mechanical agitator powerful enough to keep the seed and fertilizer in a uniform suspension in the water.

(d) Cultipacker. The roller or cultipacker shall have rollers at least 12 in. (300 mm) in diameter and shall be of sufficient weight (mass) to pulverize the clods of soil. A double gang style shall be used.

(e) Broadcast Seeders. Broadcast seeders may be hand held, tractor drawn, or tractor mounted. The seed shall drop through an adjustable flow regulator onto a rotating, horizontal disk or fan.

(f) Tractor Drawn or Tractor Mounted Drop Seeders. These seeders shall be pulled by mechanical means, have an adjustable gate opening providing uniform flow of width adapted to the work, and drop the seed directly into place on the prepared seedbed. The seeder may be of a type mounted on cultipacker rollers which covers the seed and rolls the seedbed in one operation.

(g) Rangeland Type Grass Drill and Interseeding Attachment. These seeders shall be designed specifically for the seeding of native prairie grasses and shall be approved by the Engineer prior to use. When seeding over existing turf, the rangeland type grass drill shall be equipped with a no-till interseeding attachment that is capable of cutting a slit in the soil free of leaves and debris, placing the seed in the slit, and compacting the seed into the soil of the slit.

(h) Slit Seeder. These seeders shall be self-propelled or tractor-drawn and shall be designed specifically for no-till interseeding of turf grass seed into existing turf. The slit seeder shall be capable of performing the operations specified above in Article 1101.08(g).

1101.09 Membrane Curing Equipment. Membrane curing equipment shall be as follows.

(a) Equipment for applying membrane curing shall meet the following requirements when the pavement width is 10 ft (3 m) or more. For lesser widths and for variable width pavement, the equipment shall meet the requirements of Article 1101.09(b). For the application of membrane curing compound, the mechanical equipment shall be self-propelled and shall be operated upon the pavement forms or, when a slip-form paver is used, upon the subgrade immediately adjacent to the edges of the pavement. The spraying equipment shall consist of a container having a capacity of not less than 25 gal (95 L) in which a constant pressure can be maintained by mechanical means, or a suitable pumping arrangement in order that a constant pressure at the spray nozzles will be maintained so that the membrane curing compound will be applied uniformly at the specified rate. The spray unit shall be rigidly attached and shall be equipped with mechanical devices providing constant agitation of the membrane curing compound and continuous circulation of the compound between the container and the spray nozzles. The spray nozzles shall be attached to a distributor pipe so the spray will be applied vertically from not more than 2 ft (600 mm) above the surface of the pavement, and their horizontal spacing shall be such that uniform coverage of the pavement surface will be obtained. The nozzles shall be designed so they will deliver a uniform fine spray and so that they can be easily cleaned. A suitable shield or apron shall be provided to effectively protect the spray from wind. Sufficient nozzles shall be on hand at all times so that any inefficient nozzle can be immediately replaced. Suitable means of cleaning and repairing nozzles shall also be on hand and shall be considered as being part of the spraying equipment.

(b) The equipment used to apply membrane curing compound to variable widths of pavement and other concrete construction where permitted, may be equipped with a container having not less than 5 gal (20 L) in which a constant pressure shall be maintained by a mechanical means.

(c) The equipment used to apply membrane curing compound to pavement widening shall meet the requirements of paragraph (a), except the equipment as a whole shall be mounted on a vehicle traveling on the existing pavement.

1101.10 Pavement Surface Test Equipment. Pavement surface test equipment shall be as follows.

(a) 16 ft (5 m) Straightedge. The 16 ft (5 m) straightedge shall consist of a metal I-beam mounted between two wheels spaced 16 ft (5 m) between the axles. Scratcher bolts which can be easily and accurately adjusted, shall be set at the 1/4, 1/2, and 3/4 points between the axle. A handle suitable for pushing and guiding shall be attached to the straightedge. The straightedge shall meet the approval of the Engineer.

(b) California Profilograph. The California profilograph or approved equivalent shall consist of a frame 25 ft (7.5 m) in length supported upon multiple

wheels at either end. The profile shall be recorded from the vertical movement of a wheel attached to the frame at mid point. The profile shall be recorded on a scale of 1:300 horizontally and 1:1 vertically. The profilograph shall be available to the Engineer before paving operations commence, be in working order ready to operate at time of delivery, and meet the following requirements.

(1) The profile wheel shall not be out of round or excessively worn.

(2) No frame alignment pins shall be missing and there shall be no appreciable movement of frame joints.

(3) The carriage wheels shall not be excessively worn.

(4) The steering rods shall be straight and all joints shall be tight when assembled.

(5) The rear wheels shall track the front wheels within 6 in. (150 mm).

(6) The horizontal scale on the profile shall check within 2 ft (600 mm) in 100 ft (30 m) (minimum calibration length shall be 200 ft (60 m). The vertical scale shall be true scale.

(7) An adequate supply of recorder pens and profile paper for the type of recorder unit furnished shall be provided.

(8) A reference marker shall be provided for guiding the profilograph along the profile lines 3 ft (1 m) from and parallel to the edge of pavement. The reference marker shall be reversible.

1101.11 Hydrodemolition Equipment. The equipment shall consist of filtering and pumping units operating with a remote controlled robotic device. The equipment shall be capable of removing concrete to the specified depth and of removing rust and concrete particles from exposed reinforcing bars.

1101.12 Reserved.

1101.13 Portable Shot Blast Equipment. The portable shotblast equipment shall use recyclable steel shot as an abrasive and shall include a dust collection system to provide dust free operation. Equipment shall utilize moisture and oil traps, in working order, of sufficient capacity to remove contaminants from the air and prevent oil or other contaminants from being deposited on the roadway surface. The equipment shall have an adequate air-cooled power source with a heavy duty hydrostatic transmission for variable speed operation, a variable abrasive valve for controlling the depth of cut, a small turning radius for maneuverability and a single switch one-man operation with forward and reverse capabilities. The equipment shall have an operating speed range of 0 to 160 ft/min (0 to 50 m/min) and a forward and reverse travel speed range of 0 to 350 ft/min (0 to 105 m/min). The shot feed rate shall be variable from 0 to 700 lb/min (0 to 320 kg/min) and the shot hopper shall have a capacity of 200 lb (90 kg).

1101.14 Skid Steer Loader Equipped with a Hydraulic Hammer. The skid steer loader shall be wheel mounted and hydraulically actuated, with a maximum horsepower rating of 60 hp (45 kW) and a maximum total machine weight (mass) of 6600 lb (3000 kg). The hydraulic hammer shall have a maximum impact energy of 300 ft lb (410 J) and a maximum total weight (mass) of 475 lb (215 kg). The hydraulic hammer shall be attached to the skid steer loader in such a manner that the angle of attack of the hammer is fixed while breaking concrete.

1101.15 Self-Propelled Planing Machine. The planing machine shall have a wheel base width of not less than 10 ft (3 m) and shall be capable of heating, and planing the existing surface and depositing the material into a windrow in one or more passes.

1101.16 Self-Propelled Milling Machine. Self-propelled milling machines shall be according to the following.

(a) Hot-Mix Asphalt (HMA) Surface Removal. The milling machine shall be capable of cold milling and cutting the existing HMA surface and depositing the cuttings into a windrow or directly loading the cuttings into a truck. It shall be capable of removing a lift of HMA at least 6 ft (1.8 m) in width and 1 1/2 in. (40 mm) in depth in a single pass. When the width of surface removal is less than 6 ft (1.8 m), machines less than 6 ft (1.8 m) wide will be permitted, except that the area milled shall not be wider than the width of the work specified on the plans. The milling machine shall be capable of accurately and automatically establishing profile grades by reference from either the existing pavement or from an independent grade control to provide a milled surface within a tolerance of 3/16 in. in 16 ft (5 mm in 5 m) when tested with a 16 ft (5 m) straightedge. It also shall have an effective means for removing all loose and excess material from the surface and for preventing any dust resulting from the operation from escaping into the air.

(b) Median Removal Partial Depth. The milling machine shall be self-propelled and capable of removing the portland cement concrete by a cold milling process utilizing tungsten carbide cutting teeth. The equipment shall be capable of accurately controlling the elevation and cross slope of the removal, and shall have an effective means of removing the material from the median and of preventing dust from escaping into the air.

1101.17 Asphalt-Rubber Processor/Distributor. Equipment utilized in processing and applying asphalt-rubber shall be a truck or trailer mounted self-powered distributor equipped with a heating unit, a mixing unit capable of producing a homogenous mixture of asphalt and rubber, pump(s) capable of spraying asphalt-rubber within ±0.05 gal/sq yd (±0.23 L/sq m) of the specified rate, and a fully circulating spray bar capable of applying asphalt-rubber without a streaked or otherwise irregular pattern.

The distributor shall include a tachometer, pressure gauges, volume measuring devices, an onboard weighing device to aid in proportioning materials, and a thermometer. A "bootman" shall accompany the distributor and ride in a position so that all spray bar nozzles are in his/her full view and readily accessible for unplugging.

1101.18 Mechanical Laydown Equipment. The equipment shall handle full rolls of fabric and shall be capable of laying the fabric smoothly without excessive wrinkles or folds. Stiff bristle brooms to smooth the fabric and scissors to cut the fabric shall be provided with the equipment.

SECTION 1102. HOT-MIX ASPHALT EQUIPMENT

1102.01 Hot-Mix Asphalt Plant. The hot-mix asphalt (HMA) plant shall be the batch-type, continuous-type, or dryer drum plant. The plants shall be evaluated for prequalification rating and approval to produce HMA according to the current Bureau of Materials and Physical Research Policy Memorandum, "Approval of Hot-Mix Asphalt Plants and Equipment." The plants shall not be used to produce mixtures concurrently for more than one project or for private work unless permission is granted in writing by the Engineer. The plant units shall be so designed, coordinated and operated that they will function properly and produce HMA having uniform temperatures and compositions within the tolerances specified. The plant units shall meet the following requirements.

(a) Requirements for All Plants. All HMA plants shall be according to the following.

(1) General. The plant shall be approved before production begins. All HMA plants shall be capable of producing HMA within the specification tolerances for gradation and asphalt binder content. The plant owner shall be responsible for demonstrating this capability through a production and testing program defined by the current Bureau of Materials and Physical Research Policy Memorandum, “Approval of Hot-Mix Asphalt Plants and Equipment”. If the plant fails to maintain this capability, the Department may require the demonstration to be repeated at any time. Failure to maintain the capability may result in loss of plant approval status. Accessibility to the top of truck beds shall be provided by dual platforms or other suitable device to enable the Engineer to obtain samples and mixture temperature data.

For all types of plants, the ingredients shall be heated and combined in such a manner as to produce HMA which when discharged from the plant will in general vary not more than 20 °F (10 °C) from the temperature set by the Engineer. In all cases, the mix temperature shall not be more than 350 °F (180 °C) or less than 250 °F (120 °C). Wide variations in the mixture temperature of successive loads may be cause for rejection of the HMA.

During the drying process, the moisture content of the aggregate shall be reduced such that the moisture content of the HMA at time of discharge from the mixer will not exceed 0.3 percent. For certain aggregates such as air-cooled blast furnace slag, and other highly absorptive aggregates, special handling and treatment such as double drying may be required.

Whenever a HMA plant is being used to produce High ESAL or Low ESAL mixtures as defined in Article 1030.01, all hot bins shall be

emptied and all hot and cold aggregate in the dryer and on all collector conveyors shall be removed prior to starting production or resuming once production has been interrupted for the purpose of producing a different mixture.

(2) Storage Facilities. The plant used in the preparation of the HMA shall be located where it will have adequate storage and transportation facilities. Sufficient space shall be provided for separate stockpiles of each gradation, source, and quality of aggregate required. If necessary to prevent the intermixing of the different materials, or if stockpiles join together, suitable partitions shall be used between adjacent stockpiles. All aggregates shall be kept separated until they are fed in their proper proportions onto a belt conveyor or into the boot of the cold aggregate elevator. The aggregates shall be handled in such a manner as to prevent contamination, degradation and segregation.

(3) Aggregate/RAP Feeders. The plant shall be provided with accurate mechanical means for uniformly feeding each aggregate, and RAP if used, in the proper proportions so that uniform production and uniform temperature will be obtained. A minimum of four bins and feeders for aggregate will be required. If RAP is used, one additional bin and feeder will be required. If any of the aggregates used in preparing the mixture become intermixed in a bin compartment, the compartment shall be emptied and the intermixed material shall not be used. All aggregate feeders shall be calibrated to the desired volumes and/or weights for each aggregate/mixture, to the satisfaction of the Engineer. This calibration may require plant modification. The controls of the total quantity of combined aggregates fed to the dryer shall be by a variable speed system. Other methods may be approved by the Engineer. When the proportioning gates of the aggregate feeders are once set for proper blending, they shall be locked or bolted securely and their positions shall not be changed unless directed by the Engineer.

(4) Dryers. The plant shall be equipped with a revolving cylindrical dryer or dryers capable of heating and drying all of the fine and coarse aggregates to a temperature of 250 to 350 °F (120 to 180 °C).

(5) Dust Collection. The plant shall be equipped with a primary dust collector, approved by the Engineer, connected to a secondary dust collector (baghouse or wet-wash).

Material collected from the primary collector shall be discharged into a hopper which is equipped with the means of either wasting stored dust or metering and conveying its contents into the boot of the hot elevator. Metering of dust from the hopper shall be accomplished by either an adjustable variable speed vane or auger feeder. Feed shall be actuated by a control located in the discharge chute between the dryer and the hot elevator, and shall only occur when aggregate is being discharged from the dryer. In all cases, the hopper used for storing the primary material shall be equipped with a low-bin indicator.

Material collected in the secondary collector (baghouse) shall not be stored internally, but shall be discharged directly into a silo. Feed of the material from the silo to the mix shall be accomplished only by weight (mass). In no case shall the collected secondary material be returned to the hot elevator. To meet job mix formula criteria, it may be necessary to waste some or all of the collected secondary material.

(6) Hot-Mix Surge Bins. The Contractor may use a hot-mix surge system in the manufacture of HMA provided the bin(s) meet the following requirements and are operated to the satisfaction of the Engineer. The complete surge system shall be designed and operated to prevent segregation and loss of temperature of the mix. Maximum retention time shall be eight hours unless longer retention time is authorized in writing by the Engineer. When requested, longer retention time will be evaluated according to the current Bureau of Materials and Physical Research Policy Memorandum, “Storage of Hot-Mix Asphalt”. The bin(s) shall be insulated and/or heated, and of an enclosed weatherproof type. A combination low level indicator and cutoff system shall be provided that will automatically stop the discharge of mix from the surge bin(s) when the mix falls below the top of the discharge cone. An alarm system, audible to personnel in the immediate plant area, shall be provided to sound automatically when the above system is bypassed. The conveying system used to transport the mix from the mixer to the bin(s) may be a continuous type or skip bucket type. The continuous type shall be enclosed, heated and/or insulated for effective control of mix temperature. The skip bucket must have sufficient capacity to transport an entire batch and mass dump into bin(s). Means must be provided to discharge the HMA into trucks, either from the mixer or by a diversion device, when required.

No surge system will be approved by itself but shall be considered as part of a complete operating HMA plant. The mix as discharged from the bin(s) shall meet all specification requirements for the mix being produced. Approval for the use of a surge system may be withdrawn at anytime, by the Engineer, for unsatisfactory operation.

(7) Temperature Recording Instrument. The plant shall be equipped with either a recording pyrometer or a recording thermometer having at least two terminals when a single dryer is used, and at least three terminals when a dual dryer is used. The type and accuracy of the recording instrument shall be approved by the Engineer. Unless otherwise approved, one terminal shall be installed at a suitable location at the discharge of each dryer and the others near the discharge gate in each bin compartment used for fine aggregate. The temperature recording instrument shall be capable of making accurate charts of the temperatures during the day's run. The recording instrument shall be installed at a point free from the dust and vibration of the plant. If this instrument is not located as to indicate clearly to the plant operator the temperature of the mineral aggregates at the discharge of each dryer, a non-recording pyrometer shall also be installed in view of the plant operator. At the end of each day's run, the record sheet of the recording instrument shall be submitted to the Engineer.

(8) Storage Tanks for Asphalt Binders. Tanks for the storage of asphalt binder shall be equipped to heat and hold the material at the required temperatures. The heating shall be accomplished by steam coils, hot oil coils, electricity or other approved means so that no flame shall be in contact with the tank. All asphalt lines and fittings shall be steam, electric or hot oil jacketed. Provisions shall be made for sampling the asphalt from the line leading to the weigh bucket or metering device. If more than one grade of asphalt binder is required for concurrent operations, adequate storage and separate piping to the weigh bucket or metering device for each grade, or other methods approved by the Engineer that prevent intermingling of the asphalt binders, shall be provided. An armored thermometer or pyrometer which will accurately show temperatures between 200 and 400 °F (95 and 205 °C) shall be suitably located in the asphalt line or within the tank. The instrument shall be located so as to indicate to the plant personnel, the temperature of the asphalt binder.

(9) Equipment for Weighing HMA. The HMA shall be weighed on an approved scale furnished by the Contractor meeting the requirements of The Weights and Measures Act of the State of Illinois. Each time the scale is moved, the accuracy shall be retested and certified. Platform scales, surge bin scales or surge bin hopper scales used to weigh HMA shall be equipped with automatic printers. The automatic printer shall be an integral part of the scale equipment or the scale and printer shall be directly connected in a manner that will prohibit the manual entry of weights, except as provided in paragraph a., below.

a. If the platform scale equipment measures gross weight (mass), the printer will record the gross weight (mass) as a minimum. Tare and net weights (masses) shall be shown on weigh tickets and may be printed automatically or entered manually.

b. If scale equipment on a platform scale zeros out the truck tare automatically, the printer shall record the net weight (mass) as a minimum.

c. If the scale equipment on a surge bin weigh hopper zeros automatically after discharging each batch, the printer shall record the net weight (mass) as a minimum.

d. If the scale equipment on surge bins automatically shuts down the feed system weighing and weighs the amount in the silo before and after discharge, the printer shall record the net weight (mass) as a minimum.

The automatic printer shall produce a weight ticket in triplicate. Weights (Masses) shall be shown in tons (metric tons) to the nearest 0.01 ton (0.01 metric ton).

(10) Test Measurements. Ten standard 50 lb (25 kg) weights meeting the requirements of NIST shall be available on the job site for use in

calibrating and testing the weighing equipment. The weights will not be required when the scales are calibrated by reputable, trained scale personnel with adequate scale testing equipment and the calibration is observed by the Engineer.

(11) Equipment for Anti-Strip Additives. When an anti-stripping additive is required and a liquid additive is used, it shall be added to the asphalt binder by means of an approved in-line blending system located between the plant supply tank and distribution on the heated aggregate. The in-line blending system shall be installed in such a location that the liquid additive cannot recirculate and contaminate the supply tank. The in-line blending system shall be capable of delivering a consistent and controllable stream of material to the asphalt binder under all operating weather conditions and shall be capable of controlling the introduction of additive into the asphalt binder within ±10 percent of the amount specified or required. The Contractor shall use methods and procedures for handling and storage of the additive which meet the manufacturer's safety recommendations.

When lime is used as the anti-stripping additive, a separate bin or tank and feeder system shall be provided to store and accurately proportion the lime onto the aggregate in either dry or slurry form. The lime and aggregate shall be mixed by a power driven pugmill prior to entering the dryer. In the event lime is added in dry form, the aggregate shall be dampened sufficiently to provide a uniform coating of lime. The feeder system shall be controlled by a proportioning device which shall provide accuracy to within ±10 percent of the specified amount of lime solids. The proportioning device shall have a convenient and accurate means of calibration and shall be interlocked with the aggregate feed or weight system so as to maintain the required proportion. A flow indicator or sensor shall be provided and interlocked with the plant controls such that the production of the mixture will be interrupted if there is a stoppage of the lime feed. The stockpiling of lime treated aggregate will not be permitted. The methods of introducing and mixing the anti-stripping additive and aggregate shall be subject to approval by the Engineer prior to beginning production.

(12) Equipment for RAP. When the RAP option is used, the plant shall be modified to ensure a homogenous, uniformly coated mix is obtained. A scalping screen, crushing unit or comparable sizing device shall be used in the RAP feed system to remove or reduce oversized material. Modifications shall be approved by the Engineer.

(b) Batching Plants. Batch plants shall be according to the following.

(1) Equipment for Weighing or Measuring Aggregate/RAP. The equipment shall include a means for accurately weighing each size of aggregate in a weigh box or hopper suspended on scales and of ample size to hold a full batch without hand raking or running over. The gate shall close tightly so that no material is allowed to leak into the mixer while a batch is being weighed.

If the aggregates are measured by volume in calibrated compartments, the calibrated compartments shall form the weigh hopper and shall be arranged so that the volume measurement of each compartment and each batch may be checked by weight (mass). The means of checking the volume measurement shall meet the approval of the Engineer. RAP material shall be weighed prior to entering the pugmill.

The scale shall be a springless dial scale complying with the requirements of Article 1103.02(c). Load cells with digital readouts may be used if approved by the Engineer. The scale shall have a capacity of not more than twice the weight (mass) of the approved capacity of the mixer.

(2) Mineral Filler Elevating System. The mineral filler shall be weighed in the aggregate weigh hopper or measured by volume in a calibrated compartment. It shall be conveyed to the weigh hopper by approved means. The mineral filler feeding system shall be so arranged that the accuracy of feed will not be affected by the head of material in the mineral filler bin. The feeding method shall operate in such manner as will enable small fractions of the material to be weighed. The chute used to introduce the mineral filler into the weigh hopper shall be so constructed that none of the material is retained in it after the required amount has been deposited in the weigh hopper.

(3) Equipment for Weighing or Measuring Asphalt Binder. The equipment used for weighing or measuring the asphalt binder shall consist either of an approved weigh bucket or metering device. If a weigh bucket is used, it shall be a non-tilting type and shall be completely suspended from a springless dial scale. Load cells with digital readouts may be used if approved by the Engineer. The weigh bucket, its discharge valve or valves and spray bar shall be adequately heated and shall have a capacity of at least 15 percent in excess of the weight (mass) of asphalt binder required in any batch. Adequately heated, quick-acting, non-drip valves shall be used in charging the bucket.

If a metering device is used, it shall be of an approved design and have a capacity of at least 15 percent in excess of the quantity of asphalt binder used in a batch. The controls shall be constructed so that they may be locked at any dial setting and will automatically reset to that reading after the addition of asphalt binder to the mix. The dial shall be in full view of the mixer operator. The flow of asphalt binder shall be automatically controlled so that it will begin when the dry mixing period is over. The section of the asphalt line between the charging valve and the spray bar shall be provided with a valve and outlet for checking the meter.

Either the weigh bucket or the meter device shall discharge all the asphalt binder required for one batch in not more than 15 seconds after the flow has started. The size and spacing of the spray bar openings shall provide a uniform application of asphalt binder the full length of the mixer.

(4) Accuracy of Scales. The scales shall meet the requirements of The Weights and Measures Act of the State of Illinois. The scales shall be calibrated at the beginning of each construction season and as often as the Engineer may deem necessary to assure their continued accuracy. The scales shall be inspected frequently for sensitivity, sluggishness or damage. They shall be checked for accuracy at intervals of not more than one week by obtaining the net weight (mass), on truck scales, of a truck load of HMA.

(5) Pugmill Mixer. The batch mixer shall have a rating plate attached showing the manufacturer's rated capacity, and shall be an approved type capable of producing a uniform mixture within the job tolerances. If not enclosed, the mixer box shall be equipped with a dust hood to prevent loss of dust. The clearance of the blades from all fixed and moving parts shall not exceed 3/4 in. (20 mm).

The capacity of the pugmill mixer will be determined by the Engineer based on 115 percent of the calculated net volume of the mixer below the center of the mixer shafts and 100 lb/cu ft (1600 kg/cu m) material. If the mixer will not operate efficiently at the approved capacity, or if its production does not coordinate with other plant units, the right is reserved to reduce the size of the batch until the desired efficiency is obtained. The Engineer's decision as to the permissible capacity of the pugmill mixer will be final.

The mixer shall be heated by an approved method and shall have a capacity of not less than 2000 lb (905 kg) for any composition required under these specifications. The amount of material which the Contractor will be permitted to mix per batch shall be determined by the Engineer. The mixer shall be of the twin-shaft type.

(6) Time Lock. The mixer shall be equipped with an accurate time lock to control the operations of a complete mixing cycle. It shall lock the weigh hopper gate after the charging of the mixer until the closing of the mixer gate at the completion of the cycle. It shall lock the asphalt binder bucket throughout the dry mixing period and shall lock the mixer gate throughout the dry and wet mixing periods. The dry mixing period is defined as the interval of time between the opening of the weigh hopper gate and the start of introduction of asphalt binder. The wet mixing period is the interval of time between the start of introduction of asphalt binder and the opening of the mixer gate.

The heated aggregates, RAP when used, and mineral filler shall be mixed in the pugmill mixer for a period of not less than 10 seconds. The asphalt binder shall then be added and the mixing continued. The time required to add the asphalt binder shall be not more than 15 seconds. The total time required for adding the asphalt binder and completing the wet mixing period shall be not less than 35 seconds, or longer if necessary, to produce a homogeneous mixture in which all particles of aggregate are coated uniformly. If a question as to the degree of coating should arise, AASHTO T 195 shall be used. When the RAP option is used, the mix time may vary in relation to the nature of the

aggregate. The total mixing time shall be a minimum of 45 seconds consisting of dry and wet mixing. The times of dry and wet mixing shall be set by the Engineer. The same size batch weights shall be used in the production of HMA, unless permission to change is granted in writing by the Engineer.

The control of the timing shall be flexible and capable of being set at intervals of five seconds or less throughout a total cycle. The setting of time intervals shall be at the direction of the Engineer.

(7) Batch Counter. An approved mechanical batch and/or tonnage counter shall be installed as part of the time lock device. It shall register only upon the actuation of the asphalt weigh bucket or valve release. It shall not register any dry batches or any material released during the operation of pulling the bins.

(8) Screens. The screens used in separating the aggregates shall be of the vibrating types, and when operated at normal speeds shall separate the aggregates satisfactorily. The screening system shall be equipped with a scalping screen having openings not more than 1/2 in. (13 mm) larger than the largest size aggregate used in preparing the HMA. The screening system shall have a tailing pipe for the removal of oversized aggregate. The discharge point of the tailing pipe shall be located so that it will not create a hazard or nuisance. The screens shall produce aggregate in the proper bins, as required.

Efficiency of separation based on laboratory sieves, shall be such that no more than 20 percent of the material in the bin is smaller than the nominal size nor more than ten percent over size for that bin.

(9) Hot Aggregate Bin. The plant shall be equipped with a minimum of four aggregate storage bins of sufficient capacity to supply the mixer when it is operating at full capacity. Bins shall be arranged to assure separate and adequate storage of appropriate fractions of the mineral aggregates. Separate dry storage shall be provided for mineral filler, and the plant shall be equipped to feed the material into the aggregate weigh hopper. Each bin shall be provided with overflow pipes, of such size and at such locations as to prevent backing up of material into other compartments or bins. Material from the overflow pipe shall not be returned to the hot elevator. Each compartment shall be provided with its individual outlet gate, constructed so that when the gate is closed, there shall be no leakage. Gates shall cut off quickly and completely. Bins shall be so constructed that samples can be readily obtained. A sampling device having the same width as the hot aggregate bin outlet gates shall be provided for this purpose. Hot aggregate bins shall not be modified in any manner nor shall divider plates be removed.

(c) Continuous Mixing Plants. Continuous mixing plants shall be according to the following.

(1) Gradation Control Unit. The plant shall include means for accurately proportioning each size of aggregate, RAP if used, and mineral filler.

The plant shall have a feeder mounted under each compartment bin. Each compartment bin shall have an accurately controlled individual gate to form an orifice for volumetrically measuring the material drawn from each compartment. The feeding orifice shall be rectangular with one dimension adjustable by positive mechanical means provided with a lock.

Bins shall be equipped with adequate telltale devices to indicate the position of the aggregates in the bins at the lower quarter points.

A cutoff system shall be provided which shall automatically stop the mixing operations when any bin becomes empty or when the asphalt binder reaches a level in the tank where the specified quantity of asphalt binder is not delivered to the pugmill.

Indicators graduated in 0.10 in. (2.5 mm) divisions and marked in inches (millimeters) shall be provided on each gate to show the gate opening.

(2) Weight Calibration of Aggregate/RAP Feed. The plant shall include a means for calibration of gate openings by weighing test samples. Provision shall be made so that materials fed out of individual orifices may be bypassed to individual test boxes. The plant shall be equipped to conveniently handle individual test samples weighing not less than 200 lb (90 kg). Accurate scales shall be provided by the Contractor to weigh such test samples.

(3) Synchronization of Aggregate/RAP Feed and Asphalt Binder Feed. Satisfactory means shall be provided to afford positive interlocking control between the flow of aggregate/RAP from the bins and the flow of asphalt binder from the meter or other proportioning device.

This control shall be accomplished by interlocking mechanical means or by any other positive method satisfactory to the Engineer.

A revolution counter graduated in 0.01 revolution shall be conveniently located on the plant. A convenient means shall be provided for checking, by weight (mass), the flow of the asphalt binder.

(4) Mixer. The plant shall include a continuous mixer of an approved twin shaft type that is adequately heated and capable of producing a uniform mixture within the job mix formula tolerances. It shall be equipped with a discharge hopper having a minimum capacity of 1 ton (1 metric ton), and dump gates which will permit rapid and complete discharge of the mixture. The paddles shall be adjustable for angular position on the shafts and reversible to retard the flow of the mix. The spray bar of the mixer shall be equipped with a pressure gauge. An adjustable baffle or

dam which can be locked or bolted in position shall be placed at the discharge end of the pugmill. The mixer shall have a nominal capacity, as determined by the Engineer, of not less than 60 tons (55 metric tons) per hour and shall have a manufacturer's plate giving the net volumetric contents of the mixer at the several heights inscribed on a permanent gauge. Charts shall be provided showing the rate of feed of aggregate per minute for the aggregate being used. Unless otherwise required, the mixing time shall be determined by the weight method using the following formula. The weights (mass) will be determined for the job by tests made by the Engineer.

$$\text{Mixing time in seconds} = \frac{\text{Pugmill dead capacity, lb (kg)}}{\text{Pugmill output, lb (kg) /sec.}}$$

For High ESAL and Low ESAL mixtures, as defined in Article 1030.01, the heated aggregates, mineral filler, RAP when used, and asphalt binder shall be mixed in the pug mill mixer for a period of not less than 45 seconds, or longer if necessary, to produce a homogenous mixture in which all particles of aggregate, and RAP when used, are coated uniformly. If a question as to the degree of coating should arise, AASHTO T 195 shall be used.

(d) Dryer Drum Plants. Dryer drum plants shall be according to the following.

(1) General. General requirements shall be according to Article 1102.01(a), except (3), (4), (5), and (7) will not apply, and a hot-mix surge bin meeting the requirements of (6) shall be utilized.

The heated aggregates, mineral filler, asphalt binder, and RAP when used, shall be proportioned by electronic proportioning equipment and mixed to produce a homogenous mixture in which all particles of aggregate are coated uniformly. If a question as to the degree of coating should arise, AASHTO T 195 shall be used. If the Engineer ascertains that proper mixing is not being obtained, adjustments shall be made in the plant operation (production rate, dryer drum slope, etc.) to assure that these conditions are met.

(2) Aggregate/RAP Bins and Feeders. The bins shall be designed to prevent overflow of material from one bin to another. Each bin shall be provided with a variable speed belt or apron feeder with adjustable gates which can be locked. Each bin shall have a cutoff system that shall automatically stop the feeding operation when any bin becomes empty. The combined aggregates shall pass over a vibrating scalper that will remove all material and aggregate greater than the nominal top size gradation permitted by the specification for the mixture being produced, or as set by the Engineer, prior to the aggregates being placed on the weigh belt. The scalper shall be independent of other proportioning or weighing equipment.

(3) Aggregate/RAP Weighing Equipment. The combined aggregates, and RAP if used, shall be weighed on continuous belt weighing devices meeting the requirements of the NIST Handbook #44. The weigh belts

shall be self-aligning with a gravity belt takeup and rigid wind guards at the weighing section. Sun screens may be required by the Engineer at the weighing section. Means shall be provided to divert the aggregate/RAP into a truck, after passing over the weigh belt scales. In order to obtain samples, the Contractor may choose to either stop the weigh belts when requested by the Engineer, or provide an automatic sampling device meeting the approval of the Engineer.

(4) Mineral Filler System. Mineral filler shall be proportioned to the mixing zone of the HMA plant by a variable speed vane feeder and storage system or other systems approved by the Engineer. Means must be provided to divert material from the proportioning unit for purposes of calibration. The feeder shall be provided with an automatic cutoff system in the event the feeder is blocked or is devoid of material.

(5) Asphalt Binder System. The asphalt binder system shall consist of a temperature compensating meter and pump. Other asphalt binder systems may be used if approved by the Engineer. The pump and meter shall be installed as close to the asphalt binder storage tank(s) as possible using rigid pipe with a minimum of piping length and bends. The diameter of the pipe shall be consistent throughout the system. Means shall be provided to automatically stop the plant in the event asphalt binder ceases to flow through the meter.

(6) Dryer Drum Mixer. Dryer drum mixer components shall have a minimum capacity of 60 tons (55 metric tons) per hour of HMA. The units shall have a recording pyrometer or thermometer that records the discharge temperature of the mixture.

a. Single Unit Dryer Drum Mixers. The single unit dryer drum mixer shall be a revolving cylindrical drum capable of heating, drying, and mixing the combined aggregates, RAP if used, mineral filler when required, and asphalt binder to produce a uniformly coated, homogenous HMA meeting all applicable specifications. The dryer burner shall be equipped with automatic controls.

b. Dual Unit Dryer Drum Mixers. The dryer portion of the dual unit dryer drum mixer shall be a revolving cylindrical drum capable of heating and drying the combined aggregates to the required specifications. The mixer portion of the dual unit dryer drum mixer shall be either a revolving cylindrical drum or a continuous twin shaft pugmill with a compatible mixing capacity to the dryer production rating. The unit shall be capable of mixing the heated and dried combined aggregates, RAP if used, mineral filler when required, and asphalt binder to produce a uniformly coated, homogenous HMA meeting all applicable specifications.

(7) Dust Collector. If a baghouse is utilized, the collected dust shall be returned to the dryer at a uniform rate at a point where the asphalt binder is added to the mixing zone of the HMA plant. Other dust collection systems will be permitted if approved by the Engineer.

If positive dust control equipment (PDCE) is required, it shall consist of a system that is an integral part of the production process. The system shall accurately weigh all of the secondary dust collected in the baghouse, transfer the material to a storage silo, accurately weigh the required amount of fines to be returned from the storage silo, and transfer them back to the mixture. The PDCE weighing devices shall have an accuracy of 0.5 percent of the actual weight of the material. The system shall be capable of automatically monitoring the dust collection process and adjusting the amount of asphalt binder added to the mixture. The entire system shall be interlocked with the plant controls to respond to production rate changes, start up, and shut down situations. The weighing process shall be displayed and recorded in 0.1 units. The PDCE shall be capable of accurately wasting dust without having any adverse effects on the mixture.

(8) Proportioning Control Systems.

a. Aggregate/RAP Feed Control. Each aggregate feeder shall have an adjustable feed control, which can be locked, with a master control that will automatically increase or decrease the production rate of each feeder proportionately when the total rate of production is changed. The revolutions per minute (RPM), tons/hour (TPH), etc. of all feeders shall be measured at the tail shaft of the feeder. The feeders shall have an accuracy of ±1.0 percent of the actual quantity of material delivered.

b. Aggregate/RAP Weighing. The main proportioning weigh belt shall be electronically interfaced with the asphalt binder, RAP if used, and mineral filler system to proportion the required amount of each material simultaneously to the mixer. The aggregate, and RAP if used, weighing systems shall have an accuracy of ±0.5 percent of the actual material weighed by the belts. The weighing system shall also have a high-low adjustable tolerance indicator that will signal the operator audibly when the actual production rate differs from the preset rate by more than 3.0 percent.

c. Mineral Filler Control. Mineral filler shall be added to the mixer by a variable speed proportioning system interfaced with the aggregate weigh belt that will indicate total dry aggregate combined (aggregates + mineral filler) weight (mass) to the asphalt proportioning system. The mineral filler system shall have an accuracy of ±0.5 percent if the mineral filler is measured by weight (mass), or ±8.0 percent if the mineral filler is measured solely by volume, of the actual material measured by the system. The mineral filler shall be added in the mixer at the same point the asphalt binder is added in order that no filler is lost as fugitive dust. Other systems will be permitted if approved by the Engineer.

d. Asphalt Binder Control. The required quantity of asphalt binder shall be proportioned to the mixer via a temperature compensating meter that will correct the quantity of asphalt binder to 60 °F (15 °C), or a system approved by the Engineer. This system shall

be electronically interfaced with the combined dry aggregates, RAP if used, and mineral filler. The meter shall have an accuracy of ±0.4 percent of the actual material metered.

e. Aggregate/RAP Moisture Compensators. The moisture compensation devices shall be capable of electronically converting the wet aggregate/RAP weight (mass) to dry aggregate/RAP weight (mass). Other systems will be permitted if approved by the Engineer.

(9) Control Console. The following items shall be part of the operator's control console.

a. Aggregate/RAP Feed Controls. The variable speed controls, both total and proportional for each feeder and combined aggregates or RAP if used, shall be indexed in units with a minimum unit of 0.1. The rate in RPM or TPH, etc. shall be displayed by a digital readout for each feeder with a minimum unit of 0.1 RPM or 1 TPH, etc.

b. Aggregate/RAP Weight (Mass) Indicator. The accumulated wet weight (mass) of material in tons (metric tons) that passes over each weigh belt shall be available at the control console with a minimum unit of 0.1 ton (0.1 metric ton). The dry weight (mass) of material, in TPH, passing over each weigh belt shall be displayed by digital readouts with a minimum unit of 1 TPH.

c. Mineral Filler Control. Mineral filler shall be controlled by a variable speed control with a minimum unit of 0.1 and shall be displayed in RPM, or TPH, etc. with a minimum unit of 0.1 RPM or 0.1 TPH, etc.

d. Asphalt Binder Control. The asphalt binder control shall be capable of presetting the actual asphalt binder content directly as a percent of the total weight (mass) of mixture with a minimum unit of 0.1 percent. The asphalt binder rate shall be displayed to a minimum unit of 0.1. A control shall be provided to set the specific gravity or weight/gallon (mass/liter) of the asphalt binder. The temperature of the asphalt binder shall be recorded by a recording pyrometer or thermometer at the console.

e. Aggregate/RAP Moisture Compensators. The compensators shall be part of the operator's console and shall have a minimum unit of 0.1 percent. The control shall be lockable if the moisture setting is not printed as part of the record.

f. HMA Temperature. The temperature of the mixture shall be recorded in °F (°C) by a recording pyrometer or thermometer at the console.

(10) Recording of Proportions. The plant shall be equipped with a digital printer that will automatically print the following data at six minute intervals during production time and on demand. All readings shall

show the date, month and year, and time to the nearest minute for each print.

a. Accumulated dry aggregate/RAP in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

b. Accumulated mineral filler in revolutions, tons (metric tons), etc., to the nearest 0.1 unit.

c. Accumulated asphalt binder in gallons (liters), tons (metric tons), etc., to the nearest 0.1 unit.

d. Aggregate/RAP Moisture Compensators in percent as set at the panel. (Required when accumulated dry aggregate/RAP is printed in Wet Aggregate/RAP Weight (Mass)).

Another system approved by the Engineer, such as a fully computerized system, that will provide the control and documentation of the above equipment, will be permitted.

(e) Plants Producing All Other Mixtures (as defined in Article 1030.01). Plants producing All Other Mixtures shall be according to the following.

(1) Batching Plants. The following special requirements shall apply to batching plants.

a. Article 1102.01(a)(3) shall not apply, unless aggregates are blended to achieve the required gradation.

b. Article 1102.01(b)(2) shall not apply, unless mineral filler is used to achieve the required gradation.

c. Articles 1102.01(b)(6), (7), (8), and (9) shall not apply.

(2) Continuous Plants. Article 1102.01(c)(1) shall not apply.

(3) Dryer Drum Plant. The following special requirements shall apply to dryer drum plants.

a. General. The general requirements shall be according to Article 1102.01(d), except as follows.

The plant shall be calibrated and approved prior to the start of production. Adequate means shall be provided to divert the individual or combined aggregates, and RAP if used, into a truck after the aggregates or RAP pass over the weigh belt(s) and prior to being deposited into the dryer or drum mixer. The asphalt metering system shall be calibrated at the same time as the weigh belt(s) by diverting the asphalt binder into a tank.

b. Article 1102.01(d)(3), (8) and (9) shall not apply.

c. Aggregate/RAP Feeders. The plant shall be provided with an accurate mechanical means for uniformly feeding each aggregate, and RAP if used, in its proper proportion into the dryer or drum mixer so that uniform production and temperatures will be obtained. One bin and feeder will be required for each aggregate and RAP material proportioned into the mix. Each bin shall have a low level warning device that will sound when the aggregate or RAP in any bin is less than 12 in. (300 mm) above the top of the discharge gate. A scalper or other device that will remove large clay lumps or debris will be required prior to the aggregates being placed on weigh belts. The RAP material shall be processed according to Article 1102.01(a)(12).

d. Mineral Filler System. A mineral filler system meeting the approval of the Engineer will be required when the final mix does not contain the required amount of minus No. 200 (75 µm) sieve material.

e. Proportioning Control. The combined aggregates shall pass over a weigh belt or belt scale that is electronically interlocked with the asphalt pump and will proportion the proper amount of asphalt binder at the point where the aggregate and asphalt binder are simultaneously being added to the dryer or drum mixer. RAP, if used, shall be interlocked with the aggregate weigh belt to proportion the proper amount of material to the mixing unit. The weigh belt shall have an electronic readout or display at the operator's station that shows the total ton (metric ton) per hour passing over the belt. The asphalt binder pump shall be a positive displacement type pump with a circulating asphalt system that calibrates within 0.5 percent of the theoretical asphalt at any given production rating. The asphalt binder pump shall be equipped with a revolution counter or meter and a pyrometer or thermometer probe to record the asphalt binder temperature with the data being transmitted to the operator's station.

f. Control Devices. The following items shall be part of the operator's control console.

1. Cold aggregate/RAP feed controls which indicate the relative output of each individual feeder and which have the capability of both individual and proportional control of the aggregates and RAP.

2. Dryer burner controls which automatically control the temperature of the mix and record the mix temperature at the dryer discharge.

3. Weigh belt readouts which indicate the amount of material crossing the belts.

4. Asphalt pump revolution counter or meter readout which indicates the asphalt binder being proportioned into the mix

and a recording pyrometer or thermometer which records the asphalt binder temperature prior to entering the pump.

5. Proportioning control dials for setting the asphalt content and making the moisture adjustments that are capable of being key locked.

1102.02 Reserved.

1102.03 Spreading and Finishing Machine. Hot-mix asphalt (HMA) pavers shall be self-contained, power-propelled units equipped with augers, activated screed or a strike off assembly and be capable of being heated. The augers, activated screed or strike off assembly shall be adjustable either automatically or by adding additional sections so the paver will place, compact or strike off the HMA to the full width being placed. All width extensions shall have the same placement features and equipment functions as provided on the main body of the paver. Pavers with extendible type screeds shall have a minimum 10 ft (3 m) basic screed, except on projects with 7500 sq yd (6300 sq m) or less of HMA. For these smaller projects, a minimum 8 ft (2.4 m) basic screed will be permitted. Augers shall be extended as additional sections of screed are bolted on or automatically adjustable screeds are extended. The augers need not be extended when the screed extensions on each side of the machine are 1 ft (300 mm) or less if the finished surface of the mat is uniform. Pavers used for shoulders and similar construction shall be capable of spreading and finishing HMA in widths shown on the plans. The use of any machine obsolete in design or in poor mechanical condition will not be permitted.

The spreading and finishing machine shall be equipped with an automatic electronic grade control device. The device shall be effective in leveling depressions in the surface of the existing pavement, the leveling course and the binder course.

The automatic electronic grade control device shall be capable of controlling the elevation of the screed relative to either a preset grade control stringline or a grade reference device traveling on the adjacent pavement surface. The traveling grade reference device shall be not less than 30 ft (9 m) in length.

The paver shall be equipped with a receiving hopper having sufficient capacity for a uniform spreading operation. The hopper shall be equipped with a distribution system to place the mixture uniformly in front of the screed.

The screed or strike off assembly shall effectively produce a finished surface of the required evenness and texture without tearing, shoving or gouging the mixture.

The paver shall be capable of being operated at forward speeds consistent with satisfactory placement of the mixture.

A straightedge at least 4 ft (1 m) in length and equipped with a carpenter's level shall be available at the spreading and finishing machine to check the surface of the HMA for transverse slope and longitudinal surface variations.

1102.04 Aggregate Spreaders. The aggregate spreader used in placing aggregates in layers of 1 to 12 in. (25 to 300 mm) shall be of a design approved by the Engineer. The aggregate spreader shall contain a strike off plate capable of

being adjusted so as to place the material in uniform layers from 1 to 12 in. (25 to 300 mm) in depth. It shall be equipped with two end gates or cut off plates, so that the aggregates may be spread in widths varying up to lane width.

The aggregate spreader used in spreading aggregate for surface treatments, keystone coat and seal coats shall be of a mechanical type approved by the Engineer. It shall distribute the aggregate uniformly, and shall be capable of being adjusted so that the spreading rate of the aggregate will not vary more than 2 lb/sq yd (1 kg/sq m).

The aggregate spreader used for reflective crack control treatments shall be a self-propelled machine with an aggregate receiving hopper in the rear, belt conveyors to carry the aggregate to the front, and a spreading hopper equipped with full-width distribution auger and spread rolls. The spreader shall be in good mechanical condition and be capable of applying the cover material uniformly across the spread at the specified rate.

1102.05 Pressure Distributor. The pressure distributor used for applying liquid bituminous materials shall be a self-propelled motor vehicle and shall meet the following requirements.

(a) Truck. The truck shall be capable of operating smoothly at speeds as low as 0.8 mph (1.3 km/h) when used on heavy penetration construction, and at normal road speeds when used for transporting bituminous materials. In order to develop these speeds satisfactorily, the truck shall have at least four speeds forward.

(b) Tank. The tank on the distributor shall have a capacity of not less than 600 gal (2250 L). Approval shall be obtained from the Engineer for the use of a distributor having a capacity greater than 2500 gal (9450 L). The tank shall be covered with at least 1 in. (25 mm) of approved insulation. It shall be equipped with a removable manhole cover, an overflow pipe and a suitable strainer located at the intake or outlet to the pump to prevent the passage of any material which might clog the nozzles. A dial gauge plainly visible to the spray bar operator shall be conveniently placed to indicate the contents of the tank at various levels.

(c) Heating System. The distributor shall be equipped with an approved heating system to heat the bituminous material. The heating system shall consist of heat flues having sufficient radiation to ensure the rapid circulation of hot gases of combustion from one or more efficient smokeless burners of the torch type, a circulating device to ensure uniform heating of the material, and a suitable fuel supply tank.

(d) Pump. The distributor pump shall be of the rotary positive pressure type of sufficient size and discharge capacity to apply uniformly the specified amount of bituminous material in widths up to 24 ft (7.2 m). It shall be driven in the most direct method obtainable by a gasoline motor other than the vehicle propelling motor or by other methods approved by the Engineer. The pump motor shall have sufficient power to operate the distributor pump at the required volume and pressure. If the motor pump is equipped with a transmission, it shall have a governor. Suitable housing or heating jackets

shall be provided to enclose the distributor pump and piping in order to retain the heat and to ensure a constant, even flow of the material.

(e) Spray Bars. Spray bars of various lengths shall be used to spray the bituminous material over widths varying from 4 to 24 ft (1.2 to 7.2 m). The spray bars shall be arranged so that they may be swung from side to side over a distance of not less than 9 in. (225 mm) to match joints and to clear obstructions. They shall be equipped with spray nozzles of such design and size of orifice as to ensure uniform distribution of the bituminous material in the specified quantities.

Means shall be provided to stop the flow of bituminous material quickly and to prevent it from dripping when the flow is shut off. Means shall be provided for obtaining samples of the material from the tank or from the piping leading from the tank to the spray bars.

A hand spray bar and nozzle having a suitable length of flexible hose with packed couplings shall be provided for applying material at intersections, shoulders and similar locations.

(f) Thermometer. A mercury thermometer having the stem extending into the material or into an approved well shall be placed in a suitable position in the tank to give a true average temperature of the contents of the tank.

(g) Operator's Platform. A substantial platform for the operator shall be provided at the rear of the distributor. It shall be so located that it will provide a clear view of the operation of the spray bars.

(h) Tachometer or Synchronizer. A tachometer shall be attached to the truck in such a manner as to be visible to the truck operator and to enable him/her to maintain the constant speed necessary for the correct application of the specified quantity of bitumen. Suitable charts shall be furnished showing the truck speeds necessary to obtain the required results. When a synchronizer is used, the tachometer may be omitted. The synchronizer shall deliver a specified quantity of bituminous material on the road surface regardless of the speed of the truck.

(i) Calibration. The distributor will be calibrated by the Engineer before the work is started and the Contractor shall furnish all equipment, tools, materials and assistance necessary to make the calibration.

1102.06 Reserved.

1102.07 Heating Equipment. The heating equipment shall have sufficient capacity to heat the bituminous material properly by circulating steam or hot oil through coils of the tank car or storage tank, or by any other method approved in writing by the Engineer. Tank cars which have defective coils or which are without coils will be rejected on the work by the Engineer unless some satisfactory auxiliary means can be provided by the Contractor to heat the bituminous material without the introduction of moisture. The use of any equipment to agitate the bituminous material while it is being heated will be prohibited if, in the opinion of the Engineer, it injures, or in any way changes the characteristics of the bituminous material. The use of a tank

car connection or any other equipment by means of which free steam or hot oil can be introduced directly into the bituminous material will not be permitted.

1102.08 Reserved.

1102.09 Reserved.

1102.10 Reserved.

1102.11 Micro-Surfacing Mixing Machine. The mixing machine shall be a self-propelled continuous flow mixing unit equipped with a chain dragged conveyor belt aggregate delivery system and an interconnected positive displacement gear pump to accurately proportion and deliver ingredients to a revolving multi-blade mixer and discharge the thoroughly-mixed product on a continuous flow basis. The twin-shafted multi-blade pugmill shall be a minimum of 50 in. (1270 mm) long. The emulsion shall be introduced above the third point of the mixer to ensure proper pre-mixing of the aggregate, cement, additive, and water when the modified emulsified asphalt is added. Blade size and side clearances shall meet the equipment manufacturer's recommendations. The machine shall have sufficient storage capacity for aggregate, emulsified asphalt, mineral filler and water to maintain an adequate supply to the proportioning control. The machine shall be equipped with self-loading devices which provide for the loading of all materials while continuing to lay micro-surfacing, thereby eliminating unnecessary construction joints. The mixer shall be equipped with a remote forward speed control at the back mixing platform so the back operator can control forward speed and level of mixture in the paver box or rutbox.

Individual volume or weight controls for proportioning each material to be added to the mix shall be provided. Each material control device shall be calibrated and properly marked. They shall be accessible for ready calibration and so placed that the Engineer may determine the amount of each material used at any time.

The aggregate feed to the mixer shall be equipped with a revolution counter or similar device so that the amount of aggregate used may be determined at any time.

The emulsion pump shall be the positive displacement type and shall be equipped with a revolution counter or similar device so that the amount of emulsion used may be determined at any time.

The mixing machine shall be equipped with a water pressure system and nozzle type spray bar to provide a water spray immediately ahead of and outside the spreader box. The mixing machine shall be equipped with a fines feeder that provides an accurate metering device or method to introduce a predetermined proportion of miner filler into the mixer at the same time and location that the aggregate is fed. The fines feeder shall be used whenever mineral filler is a part of the aggregate blend.

1102.12 Micro-Surfacing Spreader. The micro-surfacing spreader shall be a mechanical type squeegee box equipped with paddles mounted on adjustable shaft to continually agitate and distribute the mix throughout the box. The spreader shall be attached to the mixing machine and shall provide sufficient turbulence to prevent the mix from setting in the box or causing excessive side build-up or lumps. The

squeegee box shall be equipped with flexible seals attached to the front and rear, and in contact with the pavement surface, to prevent loss of mixture from the box. A specially designed rutbox with a steel strike off capable of placing a crown in the mix shall be provided for filling ruts. The equipment shall be capable of filling cracks and minor surface irregularities and achieving a uniform surface without causing skips, lumps, or tears in the finished surface.

SECTION 1103. PORTLAND CEMENT CONCRETE EQUIPMENT

1103.01 Concrete Mixers. Concrete mixers shall be as follows.

(a) Stationary Mixer. The mixer shall be the batch type. The mixer used for paving shall have a rated capacity of not less than 28 cu ft (0.8 cu m) of mixed concrete. The mixer shall be capable of discharging the concrete directly into truck agitators, truck mixers operating at agitating speed, or non-agitating trucks for transport to the jobsite. The mixer for structures and incidental construction shall have a rated capacity of not less than 10 cu ft (0.25 cu m) for structures involving the placement of 30 cu yd (23 cu m) or more, and not less than 7 cu ft (0.2 cu m) of mixed concrete for placements less than 30 cu yd (23 cu m).

The mixer shall be equipped with a batch meter for counting the batches, and an approved timing device which will automatically lock the discharge lever during the full time of mixing and release it at the end of the mixing period. The timing device shall be equipped with a bell, adjusted to ring each time the lock is released. If the timing device becomes broken or out of order, the Contractor will be permitted to operate while it is being repaired, provided the Contractor furnishes an approved timepiece equipped with minutes and seconds, and provided that each batch is mixed 1 1/2 minutes. If the timing device is not repaired within 72 hours, further use of the mixer will be prohibited until repairs are made.

When measuring water by volume, the mixer shall be equipped with a water measuring device which shall be capable of measuring and discharging the specified amount of water within a limit of accuracy of one percent, except a limit of accuracy closer than 1 qt (1 L) will not be required, and shall be so arranged that the accuracy of measurement will not be affected by variations in pressure in the water supply line. A water glass placed vertically on the water tank shall not be used as a water measuring device. The water measuring equipment shall include an auxiliary tank of approved design from which the water measuring tank shall be filled. The volume of the auxiliary tank shall be not less than the volume of the measuring tank. The equipment shall be so arranged that the water pressure in the measuring tank cannot exceed that due to the difference in elevation between the two tanks. The measuring tank shall be equipped with an outside tap and valve to provide for checking the graduation on the indicator, unless other means are provided for readily and accurately determining the amount of water discharged. Means shall be provided to automatically stop the flow of water from the measuring tank when the desired quantity has been delivered. If the specified amount of water can be provided without the auxiliary tank, the auxiliary tank will not be required.

When measuring water by weight (mass), the requirement for the scale shall be as specified in Article 1103.02(c), the accuracy of measuring shall be as specified above, and means shall be provided for automatically stopping the flow of water into the weighing container at the moment the correct amount has been delivered. A water meter may be used for measuring water provided it meets the requirements for automatic stop of the flow of water and accuracy of measurement.

Pickup and throw-over blades in the drum of the mixer which are worn down 3/4 in. (20 mm) or more in depth shall be replaced with new blades.

(b) Truck Mixer. Truck mixers shall be either the type having a watertight revolving drum, suitably mounted and fitted with adequate blades attached to the drum, or the type having an open-top, watertight, trough-like container, suitably mounted and fitted with adequate blades revolving about an axis parallel to the axis of the trough. Truck mixers shall be capable of combining materials into a uniform mixture, and of discharging the mixture without segregation.

Truck mixer blades at the point of maximum drum diameter, nearest to the drum head, shall not be worn more than ten percent of the original radial height. The radial height shall be determined according to the National Ready Mixed Concrete Association's Certification of Ready Mixed Concrete Production Facilities/Plant Certification Check List document, the blade dimensions provided by the manufacturer, or other available information.

Truck mixers, except when used exclusively for agitating premixed concrete, shall be provided with a batch meter and locking device capable of preventing the discharge of the concrete before the required number of revolutions has been obtained, or with an approved revolution counter, suitably mounted, to provide a means of verifying the amount of mixing obtained.

The water measuring device shall be capable of measuring and discharging the specified amount of water within a limit of accuracy of one percent, except a limit of accuracy closer than 1 qt (1 L) will not be required. If the water is added during transit, the measuring device may be mounted upon the truck mixer, and an outside tap or valve shall be provided for checking the graduations on the indicator, unless other means are provided for readily and accurately determining the amount of mixing water discharged. Provisions shall be made to automatically stop the flow of water when the desired amount has been delivered. If not mounted on the truck mixer, the water measuring device shall be located at the site selected for adding the water, and shall be according to the requirements of Article 1103.01(a). A water glass placed vertically on the water tank shall not be used as a water measuring device, except for final slump adjustment at the job site.

The equipment for weighing and batching the materials for truck mixing shall be according to Article 1103.02.

The truck mixer shall be approved before use according to the Bureau of Materials and Physical Research's Policy Memorandum, "Approval of Concrete Plants and Delivery Trucks".

(c) Truck Agitator. Truck agitators shall be either the type having a watertight revolving drum, suitably mounted and fitted with adequate blades attached to the drum, or the type having an open-top, watertight, trough-like container, suitably mounted and fitted with adequate blades revolving about an axis parallel to the axis of the trough. The truck agitator, when fully loaded, shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass, and of discharging the concrete without segregation. For the open-top truck agitator, a watertight cover shall be used to protect the concrete when it is raining.

The truck agitator shall be approved before use according to the Bureau of Materials and Physical Research's Policy Memorandum, "Approval of Concrete Plants and Delivery Trucks".

(d) Nonagitator Trucks. Nonagitator trucks shall have a metal container that is smooth, watertight, and non-reactive to concrete. Nonagitator trucks shall be capable of discharging the concrete at a satisfactorily controlled rate and without segregation. A watertight cover shall be used to protect the concrete when it is raining.

The nonagitator truck shall be approved before use according to the Bureau of Materials and Physical Research's Policy Memorandum, "Approval of Concrete Plants and Delivery Trucks".

1103.02 Batching and Weighing Equipment. The plant shall be approved before production begins according to the Bureau of Materials and Physical Research's Policy Memorandum, "Approval of Concrete Plants and Delivery Trucks". The bins, weighing hoppers and scales shall be arranged to the satisfaction of the Engineer so that the weigh beam "telltale" dial, or the dial scale, or the digital readout is in full view of the operator controlling the gates, valves or belts that feed the material into the weighing hopper. The equipment used for batching and weighing the materials shall comply with the following requirements.

(a) Bins and Silos. Bins and silos shall have sufficient capacity for adequate supply of materials to the weighing hoppers. They shall be supported by rigid frame work on a safe foundation. Portable type bins and silos shall be fully loaded and permitted to stand for at least 12 hours before operations start. Bins and silos shall have separate compartments for each aggregate, cement, and finely divided mineral used. Except for permanently located plants, the top of the fine aggregate compartment shall be equipped with a tilted screening device which shall reject all material coarser than 1 in. (25 mm) and through which all fine aggregate must pass upon entering that compartment. Each compartment shall be designed to discharge material efficiently and freely into the measuring hopper.

Means of control shall be provided so that when the quantity to be obtained is being approached, the flow of the material can be gradually retarded and

completely shut off, without leakage, at the moment the desired amount has been discharged.

(b) Weighing Hoppers. The hoppers shall be completely suspended from the scales and shall otherwise hang free and, except as further provided, shall have sufficient capacity to contain the material or materials to be weighed for one batch without shoveling and without jiggling the hopper to keep bin gates and chute openings free of material during the weighing. Cement shall be weighed in a hopper entirely free and independent of the hopper or hoppers used for weighing the aggregate. When manually batching, finely divided minerals shall be weighed in a separate hopper. Finely divided minerals may be weighed into the cement weigh hopper for automatic or semi-automatic batching.

Batching equipment, insufficient in capacity to weigh the materials required for a full batch, will be permitted for stationary mixers and truck mixers provided that the capacity of the hopper or hoppers is sufficient to weigh all the materials for at least 1 cu yd (0.75 cu m) of concrete for any mixer of rated capacity of 1 cu yd (0.75 cu m) or larger. The batching equipment shall be limited to a maximum of three weighings of each material for charging the mixer.

All hoppers, except cement, shall have a port or other opening for removal of overload of any one of the materials unless sufficient clearance for this purpose exists between the bottom of the bin gate and the top of the hopper. The top of the cement hopper shall be closed to prevent the escape of cement while it is being weighed. Hoppers shall be constructed in a manner that will eliminate the accumulation of tare material and leakage through the discharge gates during weighing. They shall be capable of discharging the material efficiently and completely into the batch trucks or mixer without the necessity of beating or jiggling. If any hopper, in the opinion of the Engineer, does not discharge the material satisfactorily, it shall be provided with a vibrator of sufficient frequency and power to assure complete discharge. For cement and finely divided minerals, a device shall indicate the complete discharge of materials. All weighing hoppers shall be enclosed or otherwise protected against wind.

(c) Scales. The scales may be of either the horizontal beam or the springless dial type, shall be designed as an integral unit of the batching equipment, and shall be constructed to withstand the usage for which they are intended. Load cells with digital readouts may also be used.

Beam type scales shall have as many beams and of such capacities as will permit the required weight (mass) of each aggregate to be set off on a single beam, except that when one aggregate is required, two weigh beams will be permitted. The scale shall be provided with suitable lockouts so that the weigh beams may be engaged to weigh in the desired order. Each weigh beam shall have some means or device to indicate when the beam is in the proper balance position. Poises shall be constructed so that they will be held firmly in position. Beam scales shall have provisions such as a "telltale" dial for indicating to the operator that the required load in the hopper is being approached. Such device shall indicate at least the last 200 lb (90 kg) of

load in the case of scales used for weighing aggregate, and at least the last 100 lb (45 kg) of load in the case of scales used for weighing cement and finely divided minerals, and shall be placed in a position from which it can be viewed without parallax by the operator while charging the hopper.

Except for permanently located plants, springless dial scales shall be provided with suitable markers inside the glass cover and in front of the dial which may be set to show the position of the dial indicator for the required load or the various accumulative loads when more than one aggregate is weighed in the same hopper. Markers shall have distinctive colors for the various materials to be weighed. Dials shall be placed so that they can be viewed without parallax by the operator.

The value of the minimum graduation interval of any scale used for weighing materials shall be not more than 0.2 percent of the batch weight (mass) and not more than 0.1 percent of the capacity of the scale, except that graduation intervals less than 5 lb (2 kg) when weighing aggregates and less than 2 lb (1 kg) when weighing cement and finely divided minerals will not be required. In the case of beam scales, the same requirement shall also apply to the graduation of each individual beam with respect to the weight (mass) of material normally weighed on it. The value of the minimum graduation interval of any scale used for weighing mixing water shall be not less than 2 lb (1 kg). All scales shall be designed and built to a maximum tolerance of 0.4 percent of the net load in the hopper.

Cement shall be weighed on a scale separate and distinct from the scale or scales used for weighing other materials. Mixing water, when weighed, shall be subject to the same requirement as cement. Finely divided minerals shall be weighed on a separate scale unless the batching equipment is automatic or semi-automatic. When a beam scale is used for weighing cement, a tare beam shall be provided and the weigh beam or beams shall be capable of being lifted out of weighing position so that the tare weight (mass) of the hopper can be checked after each weighing operation to determine if all of the cement or finely divided minerals has been discharged into the batch.

Scales shall be housed or otherwise protected against the effect of wind in a manner meeting the approval of the Engineer.

Ten standard 50 lb (25 kg) weights meeting the requirements of NIST shall be available on the job site for use in calibrating and testing the weighing equipment. The weights will not be required when the scales are calibrated by reputable, trained scale personnel with adequate scale testing equipment and the calibration is observed by the Engineer. Scales shall be calibrated at the beginning of each construction season or each 12 month period, and each time the scales are moved, or when scale components are repaired or replaced.

Once a scale is calibrated, the settings shall not be altered. The concrete producer shall submit for approval by the Engineer, a method to verify the settings have not been altered. If at any time the Engineer determines the settings have been altered, a new calibration will be required.

Means of access for inspection purposes shall be safe and shall meet the approval of the Engineer. In the case of permanently located plants, the means of access shall be an inclined stairway with the handrail located so that its upward flight will end on the scale operator's platform. It shall be firmly attached to the supporting members of the bin. The weigh platform shall have an approved floor of metal grid or 2 in. (50 mm) plank.

(d) Slurry Mixer. A slurry mixer may be used to premix cement, finely divided minerals, water, and admixtures before discharge into a stationary mixer or truck mixer. The equipment shall be a vortex type, paddle type, or other type approved by the Engineer. The vortex type shall have an impeller for mixing. The paddle type shall have mixing blades and paddles for mixing.

The batching equipment shall have a moisture sensor to measure the fine aggregate moisture, when the slurry mixer is operated. The cement, finely divided minerals, and water shall be measured in the slurry mixer, according to Article 1020.10. The mixing of materials in the slurry mixer shall result in a uniform mix, which shall flow into the stationary mixer or truck mixer.

The batching equipment shall have the ability to batch cement and finely divided minerals with or without the use of the slurry mixer.

1103.03 Automatic and Semi-Automatic Batching Equipment. Automatic equipment for weighing, measuring, batching and mixing materials shall be according to Articles 1103.01 and 1103.02, except as follows.

(a) General Requirements. It is the purpose of the requirements set forth herein that automatic and semi-automatic batching equipment shall render impossible the omission of any one of the required materials from any batch, and that duplications of measurement of any one material into any batch shall not occur. Further, it is the intent that the amounts of materials entering into any batch shall be accurately measured within the specific tolerances set forth herein. In the case of stationary mixers, it is intended that each batch shall be mixed during the full period required after all the materials have entered the mixer, and that recharging the mixer shall not occur before the previous batch has been discharged. Certain requirements to further the objects stated are as follows.

(1) Allowable Tolerances. Aggregates measured individually or cumulatively, shall have a tolerance within ±1 1/2 percent of the required quantity. Cement and cementitious materials measured individually or cumulatively, shall have a tolerance within ±1 percent of the required quantity. Water shall be measured to a tolerance within ±1 percent of the required quantity. Admixtures shall be measured to a tolerance within ±3 percent of the required quantity. The interlock control shall be set to the required tolerance.

(2) Weighing Control. Arrangement shall be such that any scale of the system can be conveniently checked for accuracy at any time that this should be considered desirable. All scales shall be designed and built so that, when any drag due to weighing control devices is included, an

accuracy within the maximum tolerance of 0.4 percent of the net load in the hopper will be maintained.

(3) Water Measuring Control. When the mixing water is measured volumetrically, provisions shall be made for bypassing the measured water into a container for checking the accuracy of delivery. If the water is measured during the course of its flow into the batch, means shall be provided to show, at any time during the flow, the amount that has entered. Devices for volumetric measurement of mixing water, in the case of automatic systems, shall automatically reset at the initial position immediately after delivery of the measured amount, ready for the next succeeding batch cycle.

(4) Admixture Control. The dispenser for an admixture shall meet the requirements for automatic or semi-automatic batching. Liquid admixtures shall be protected from freezing and contamination. Agitation shall be provided for liquid admixtures which are not stable solutions.

To provide a visual indication the liquid admixture is actually entering the batch, the tube conducting the admixture into the stream of mixing water or directly on the aggregate shall be transparent or translucent, or shall have a transparent or translucent section. If approved by the Engineer, an alternate indicator may be used for high range water-reducing admixtures and corrosion inhibitor admixtures.

The dispenser's visual indicator shall be easily viewed by the plant operator when batching. Televised images may be used.

(5) Control of Mixing Time. When automatic or semi-automatic batching equipment, in connection with stationary mixers, are used for successive batches of the same size, the mixing time adjusting control shall be capable of being locked with a key.

(b) Automatic Batching Equipment. Automatic batching equipment shall be provided with gates, valves, or other suitable devices, which, when activated by a single starting mechanism, shall set in motion the charging of weigh hoppers or other containers, and which, in weighing or measuring any given material, shall automatically stop the flow of that material when the desired amount, within the allowable tolerance, has been attained. Automatic batching equipment shall be capable of having quantities preset on a central control panel that will result in correct measurement of each material for each batch, and control adjustments shall be capable of being performed on that panel.

For any material measured by weight (mass), a suitable "over" and "under" indicating device shall be provided, showing whether the amount of material weighed is within the allowable tolerance. Interlock shall be provided (1) so that the charging device can open or start only when the scale indicates zero load and when the weigh hopper or container discharging gate or valve is closed, and (2) so that the discharging gate or valve can open only when the desired weight (mass) within the allowable tolerance is in the weigh hopper

or container and when the charging device is closed or stopped. If more than one aggregate is weighed cumulatively into the same hopper, control and interlock shall be provided with respect to each increment of weighing, as required for a material weighed into an individual hopper. It shall not be mandatory that the mixing water and air-entraining admixture be measured by weighing. These materials may be measured volumetrically, if the specified controls, or other equally effective means are provided, and if the measurements are within the specified tolerance.

Automatic batching equipment for weighing or measuring batch quantities in increments shall be provided with an automatic repeater having a counter that can be set for the number of increments required, and which shall ensure that the required number of increments are accurately delivered and discharged into each batch.

An automatic batching system shall consist of the combination of automatic batchers necessary for batching the materials required. All shall be activated by a single starting mechanism and the system shall be completely interlocked. In the case of stationary mixers, interlock shall be provided so that the discharging gates or valves can open only when the mixer is in the proper position for receiving the materials. The interlock of the system, with respect to sequence of discharge of the materials into the mixer, shall be such that the mixing water and air-entraining admixture are discharged according to the requirements of Articles 1020.08 and 1020.11.

Means shall be provided for convenient adjustment, from preset quantities, of the amounts of the aggregates, the mixing water and the air-entraining admixture, as based on tests of the aggregates and observations and tests of the mixture being produced. Suitable equipment indicating the amount of free water in the fine aggregate, as it is being batched, shall be provided, and the quantities of fine aggregate and mixing water shall be adjusted currently, as concrete is being produced, so that the desired amounts of these materials enter into each batch. Other adjustments of the quantities, as preset for automatic control, shall be made only at the direction of the Engineer.

The operator shall not interfere with the operation of any part of the scale mechanism during the weighing process for the purpose of circumventing the interlock or malfunction of the equipment. Failure to comply with this requirement shall be cause for the Engineer to require that the equipment be provided with a positive means for preventing such interference.

A batching system consisting of a combination of semi-automatic batchers, as described below, and automatic batchers may be approved, provided that control and interlock shall be as prescribed for automatic batchers.

(c) Semi-automatic Batching Equipment. Batching equipment which does not substantially comply with all the requirements prescribed for automatic batching equipment, but which meets at least the following described minimum conditions, will be considered as semi-automatic batching equipment.

As a minimum requirement, semi-automatic batching equipment shall be provided with gates, valves or other suitable devices, which open or start separately, when actuated by individual starting mechanisms, to permit the material to be weighed or measured, and close or stop automatically when the desired amount, within the allowable tolerance, has been attained. Interlock with respect to individual units and "over" and "under" indicating devices shall be provided as prescribed for automatic batching equipment.

Other features prescribed for automatic batching equipment may be incorporated and approved.

A semi-automatic batching system shall consist of the combination of semi-automatic batchers necessary for batching the materials required. The system may be partially or completely interlocked.

For semi-automatic batching systems constructed so that materials are batched at more than one stop or location, a separate control panel shall be furnished at each location, unless the operations can be controlled from a central location in a manner that will ensure that the correct amount of material is included in each batch. In the event that movement of trucks receiving the batches is necessary during the operations at any location, a separate control panel shall be provided at that location, and an operator shall be present to ensure that the batches are discharged correctly into their respective compartments. However, if effective interlock is provided between the movement of trucks and the batching mechanism so that batches can be discharged only as required without omission or duplication, and as each batch compartment is brought into correct position, then the operations may be conducted from a centrally located control panel.

The operator shall not interfere with the operation of any part of the scale mechanism during the weighing process for the purpose of circumventing the interlock or malfunction of the equipment. Failure to comply with this requirement shall be cause for the Engineer to require that the equipment be provided with a positive means for preventing such interference.

A batching system consisting of a combination of semi-automatic and manual batchers may be approved, provided that satisfactory control of the batching is attained.

(d) Manual Operation. Automatic and semi-automatic batching equipment may be constructed so that they can be switched to manual control. When switching to manual control is necessary, the batching operations shall continue only until repairs can be made, but not for a period exceeding 72 hours, unless otherwise approved by the Engineer.

If provision is made for switching to manual operation, then the scale, or a scale follower approved by the Engineer, shall be placed within easy view of the operator, but not farther than 20 ft (6 m) from the location from which the manual batching is being performed. Dial scales shall be placed so that they can be viewed without parallax.

1103.04 Mobile Portland Cement Concrete Plants. The mobile concrete plant shall meet the following minimum requirements.

(a) The mixer shall be capable of carrying sufficient unmixed materials to produce not less than 6 cu yd (4.6 cu m) of concrete.

(b) The mixer shall be capable of positive measurement of cement being introduced into the mix. A recording meter visible at all times and equipped with a ticket printout shall indicate this quantity.

(c) The mixer shall provide positive control of the flow of water into the mixing chamber. Water flow shall be readily adjustable for variations in aggregate moisture.

(d) The mixer shall be capable of being calibrated to automatically proportion and blend all components on a continuous or intermittent basis, as required by the finishing operation, and shall discharge mixed material through a conventional chute.

(e) The mixer shall be calibrated annually by a commercial testing laboratory. Copies of calibration charts shall be maintained in the truck and also the District office.

(f) The mixer shall be maintained clean and in good repair.

(g) The mixer shall meet all requirements of AASHTO M 241.

1103.05 Forms. Forms for pavement, concrete gutter, curb, median and paved ditches shall be as follows.

(a) Pavement. Flexible or curved forms of proper radius, made of either metal or wood, shall be supplied for use on curves of 100 ft (30 m) radius or less.

At all other locations, unless approved by the Engineer, side forms for pavement shall be metal. They shall be of an approved cross section, and shall be furnished in sections not less than 10 ft (3 m) in length. They shall have a height not less than the edge thickness of the pavement to be constructed, a base width equal to or greater than the height and shall be made of metal not less than 1/4 in. (6 mm) in thickness, except that a minimum thickness of 3/16 in. (5 mm) will be permitted if the form is of trapezoidal cross section. They shall have flange braces extending outward on the base not less than 2/3 the height of the form and spaced not more than 5 ft (1.5 m) apart. Each section shall have a steel pin at each end and at least one intermediate pin, and provision shall be made to lock all pins to a true grade. Locked joints shall be provided between form sections to maintain the alignment and elevation of the form line. Metal forms shall withstand loading imparted by the paving train without distortion or settlement of the form line. They shall be straight and free from warp. Any form varying on its upper edge more than 1/16 in. in 10 ft (2 mm in 3 m) from a straight line will be rejected. The longitudinal axis of the upstanding leg shall not vary more than 1/4 in. in 10 ft (6 mm in 3 m) from a straight line.

The use of wood forms will not be permitted unless approved by the Engineer. When used, wood forms shall be made of well seasoned, surfaced plank, shall be not less than 2 in. (50 mm) thick (commercial dimensions), with the exception of curved or flexible sections, and shall be the full depth of the concrete slab; shall be straight and free from warp; shall provide for rigid, smooth connections; and shall provide ways and means to be securely fastened in place to the lines and grades given.

Metal forms that will be used to support a vibrating screed shall be made of no less than 10 gauge (3.4 mm) steel with a minimum 4 in. (100 mm) wide base and have a minimum of two flange braces with provisions for pin locking in each 10 ft (3 m) section.

Metal pins shall be of proper size and length to hold the forms rigidly and securely in place.

Metal forms may be built-up with a single layer of wood plank, 2 in. (50 mm) thick or less when the specified pavement thickness differs from standard manufactured form sizes. The wood plank shall be well seasoned surfaced hardwood free from warp and twist. The plank shall be attached to the bottom of the metal form with two lines of bolts at not more than 2 ft (600 mm) centers on each line. The width of the plank shall equal or exceed the pavement thickness.

(b) Concrete Gutter, Curb, Median and Paved Ditch. The forms shall be of wood or metal, straight and free from warp, and of sufficient strength to resist springing during the process of depositing the concrete against them. Wood forms shall consist of 2 in. (50 mm) surface plank, except wood forms less than 2 in. (50 mm) thick may be used for short radii. Metal forms shall be of an approved section and shall have a flat surface on the top. Forms shall be so designed that divider plates or other devices for holding the form in place will not cause planes of weakness in the concrete and subsequent cracking. The forms shall be of a depth of the curbing, median or paved ditch, and so designed as to permit secure fastening together at the tops.

1103.06 Reserved.

1103.07 Reserved.

1103.08 Subgrade Planer. The subgrade planer shall be of steel and be mounted on rollers or wheels. It shall be equipped with steel cutting edges or cutting rollers, so designed that they may be accurately adjusted vertically. The subgrade planer shall be of sufficient weight (mass) so as not to rise from the pressure of the material being planed. The subgrade planer shall produce a cross section in accordance with the plans and shall not develop a center deflection of more than 1/8 in. (3 mm).

1103.09 Subgrade Machine. The subgrade machine shall be self-propelled and mounted on crawler type tracks. It shall be equipped with a rotating drum fitted with cutting teeth capable of cutting and trimming earth, aggregate and hot-mix asphalt, and so designed that they may be accurately adjusted vertically and held in

place. The machine shall have a moldboard to provide the final surface and texture. It shall weigh not less than 7000 lb (3200 kg) and shall have such strength and rigidity that it will not develop a center deflection of more than 1/8 in. (3 mm).

The subgrade machine shall be equipped with an automatic electronic grade control device. The device shall be capable of controlling the elevation of the subgrade machine relative to either a preset grade control stringline or a traveling grade reference. The method of grade control shall be approved by the Engineer.

1103.10 Reserved.

1103.11 Water Supply Equipment. The water supply equipment shall be of such capacity and design as to ensure an ample supply and adequate pressure simultaneously for all of the requirements of machinery, mixing, curing, wetting subgrade, and all other features of the work.

1103.12 Mechanical Concrete Spreader. The mechanical concrete spreader shall be approved by the Engineer. The spreader shall run on forms when forms are used or on wheels or tracks when slip forming. The mechanical concrete spreader shall be self-propelled and shall be capable of spreading the concrete mix to the desired cross sections. The spreader shall be easily adjustable to spread different elevations of concrete. Vibrators may be attached to the spreader, finishing machine or may be mounted on a separate carriage and shall avoid contact with the joints, load transfer devices, reinforcement, subgrade, subbase, or side forms.

The vibrating impulses shall be applied through an apparatus especially designed for this purpose and so constructed as to operate satisfactorily ahead of the finishing machine in such a manner that the vibratory impulses are transmitted through the concrete mass with sufficient intensity to consolidate it throughout its entire depth and width. Vibrators shall be used only for purposes of consolidation.

Surface pan type vibrators shall be so designed that the vibrating impulses will be applied directly to the surface of the concrete. The surface pan type vibrator shall be equipped with a minimum of two vibrating elements for each lane width of pavement vibrated. The operating frequency shall be 3500 VPM or greater.

Vibrators of the internal type shall be especially designed for this purpose and so constructed as to operate satisfactorily. The operating frequency of the internal type shall be 7000 +/- 2000 VPM. The vibrating elements shall be so spaced that the concrete mass shall be consolidated throughout its entire depth and width, but the spacing of the vibrating elements shall be 24 in. (600 mm) or less.

A vibrating reed tachometer, hand type, shall be provided with each paver. The vibrating reed tachometer shall have a range from at least 4000 to 10000 VPM.

For a contract which has a minimum of 10,000 sq yd (8350 sq m) of pavement that is 12 ft (3.6 m) or more wide, an electronic internal vibrator monitoring device shall be provided. The device shall be capable of displaying the operating frequency of each internal vibrator, and shall be visible to the paving operator. The vibrator monitoring device shall have a range from at least 4000 to 10,000 VPM.

1103.13 Finishing Machine. Finishing machines for portland cement concrete bridge decks and pavement shall be according to the following.

(a) Bridge Deck. The finishing machine shall be equipped with: (1) a mechanical strike off device; (2) either a rotating cylinder(s) or a longitudinal oscillating screed which transversely finishes the surface of the concrete; and (3) fogging equipment. The Contractor may attach other equipment to the finishing machine to enhance the final finish when approved by the Engineer. The finishing machine shall produce a floor surface of uniform texture, free from porous areas, and with the required surface smoothness.

The finishing machine shall be operated on rails or other supports that will not deflect under the applied loads. The supports shall be adjustable for elevation and shall be completely in place for the full length of the area to be finished. The supports shall be approved by the Engineer before placing of the concrete is started.

(b) Pavement. Finishing machines for pavement shall be according to the following.

(1) The finishing machine shall be designed for concrete paving and meet the approval of the Engineer. The finishing machine shall be power driven with at least two oscillating screeds or a pan type screed which shall be capable of placing, spreading, consolidating, screeding, and finishing the concrete to the proper pavement elevation and cross section within the specified tolerance.

The pan type paver shall be equipped with augers, strike off and tamper bars ahead of the pan screed with at least one trailing oscillating screed or belt finisher. The pan shall be sufficiently braced and stiffened to ensure no deflection. Internal vibrators with pressure compensating controls meeting the requirements of Article 1103.12 shall be attached to the paver. If the paver is powered by cable and motor, a steering sensor shall be required and the motor shall be hydraulically operated. One switch or control, which stops or starts all paver functions simultaneously, shall be provided.

(2) Other types of power driven finishing machines, exclusive of vibratory screeds and truss-type vibratory screeds, which are specifically designed for finishing concrete pavement or bridge decks and meet the approval of the Engineer, may be used under the following conditions.

a. Restricted clearance outside the forms.

b. Mainline pavements with a posted speed of less than or equal to 40 mph (65 km/h).

c. Where a continuous line of forms more than 600 ft (180 m) cannot be set. Railroad tracks, bridges, existing paved intersections, or gaps shown in the plans or ordered by the Engineer shall be considered as obstructions in the continuity of the form line.

d. Bridge approach pavement, shoulder pavements, and connections.

The use of a mechanical concrete spreader may be waived provide the concrete hauling equipment is equipped with a discharge system capable of distributing the concrete uniformly without segregation across the subgrade or subbase.

1103.14 Concrete Finisher Float. The concrete finisher float shall be either self-propelled or attached to a finishing machine. The float shall be easily adjustable from crown to flat. The float shall be a minimum of 30 in. (750 mm) in length with a minimum of 24 in. (600 mm) in contact with the concrete. It shall be so designed to prevent tearing of the concrete surface or rolling of aggregate under the float. The float pan shall be suspended from the frame, float freely on the concrete, and shall be capable of being adjusted in both height and width. The float pan, once adjusted, shall be equipped hydraulically or by other suitable means that it may be raised from the operator's platform and when lowered shall automatically return to its preset position. If self-propelled, it shall also be equipped with four or more wheels which ride on the forms and it shall be of sufficient weight (mass) as to resist flexing under the pressure of the concrete.

1103.15 Mechanical Longitudinal Float. The machine shall be so constructed that the travel of the floating mechanism can be adjusted to conform to the pavement cross section, elevation, and surface smoothness shown on the plans. The float shall be a minimum of 10 ft (3 m) in length and 1 ft (300 mm) in width. It shall be equipped with a power driven floating screed and shall oscillate longitudinally with respect to the pavement during its transverse travel across the pavement. It may be either attached to the finishing machine or formless paver, self propelled on rollers operating on forms or self propelled operating on tracks. If attached to a finishing machine or formless paver, it shall be rigidly supported by a frame at the rear in a manner approved by the Engineer. If self propelled, the tracks or rollers from which the float operates shall be in good working condition. The tracks or rollers from which the float operates shall be accurately adjusted and coordinated with the adjustments of the finishing machine or formless paver so that a small amount of mortar is carried ahead of the float at all times.

1103.16 Formless Paver. The formless paver shall be self-propelled and equipped with suitable devices for spreading, strike off, consolidation, and finishing of concrete the full-width and depth as shown on the plans without the use of fixed side forms. The tracks shall be of sufficient length and width to properly support the machine and its load without causing excessive depressions. The formless paver shall be equipped with strike off screed, and internal vibrators of sufficient quantity to provide complete consolidation regardless of the depth of concrete placed. Vibrators shall meet the requirements of Article 1103.12. The paver shall be capable of constructing pavement to line and grade specified. The method of placing the concrete in front of the formless paver shall be a separate operation as specified in Article 1103.12 without being attached to the formless paver.

The formless paver shall be approved by the Engineer prior to starting the paving operations.

1103.17 Miscellaneous Equipment. Miscellaneous equipment shall be as follows.

(a) Hand Vibrator. The vibrator shall be the internal type. It shall be adequately powered to operate under full load at a frequency of 4500 VPM or greater; and shall have an intensity and period of vibration sufficient to obtain thorough consolidation of the concrete.

The vibrator shall have a non-metallic head for areas containing epoxy coated reinforcement. The head shall be coated by the manufacturer. The hardness of the non-metallic head shall be less than the epoxy coated reinforcement, resulting in no damage to the epoxy coating. Slip-on covers will not be allowed.

(b) Hand Tamper. Hand tampers, when required or permitted under these Specifications, shall meet the approval of the Engineer.

(c) Header. The header shall be shaped to conform to the cross section required by the plans. It shall be wood or metal and of sufficient thickness and rigidity to provide a vertical construction joint. The header for continuous reinforced pavement shall be of wood or metal and shall be split longitudinally to provide for the proper depth of the continuous reinforcement steel according to the plans.

(d) Foot Bridge. Foot bridges shall be durably constructed and readily movable. They shall be so designed that no part of the bridge will come in contact with the pavement at any time. Two or more foot bridges shall be provided.

(e) Hand-Operated Longitudinal Float. The hand-operated longitudinal float shall be at least 10 ft (3 m) in length and properly stiffened to prevent flexibility and warping during the finishing operation. The handle shall be at least 3 ft (1 m) longer than 1/2 the width of the slab.

(f) Long-Handled Float. The long-handled float shall have a blade at least 3 ft (1 m) in length and 6 in. (150 mm) in width. The handle shall be of such length as will permit the operation of the float from the shoulder. Two or more such floats shall be provided.

(g) Vibrating Screed. The screed used to strike off and consolidate the concrete by the hand method shall be durably constructed, equipped with a vibrator, and shall be shaped to provide the cross section as shown on the plans. The screed shall be at least 2 ft (600 mm) longer than the maximum width of the slab to be struck off. It shall be an approved design and be constructed either of metal or of other suitable material shod with metal.

(h) 10 ft (3 m) Straightedge. The 10 ft (3 m) straightedge shall be made of suitable material, and shall be maintained in accurate alignment at all times. It shall be equipped with a handle at least 3 ft (1 m) longer than 1/2 the width of the slab. Two or more 10 ft (3 m) straightedges shall be provided.

(i) Broom. Brooms shall be of push broom type, at least 18 in. (450 mm) in width. They shall contain a maximum of three rows of good quality bass or bassine fiber 4 1/2 in. (115 mm) or less in length. The handle shall be at least 1 ft (300 mm) longer than 1/2 the width of the slab and shall be readily adjustable. Two or more brooms shall be provided.

(j) Edging Tool. The edging tools shall have a radius of 1/4 in. (6 mm), and shall be approved by the Engineer. Two or more edging tools shall be provided.

(k) Fogging Equipment. Fogging equipment shall consist of a mechanically operated, pressurized system using a triple headed nozzle or an equivalent nozzle. The fogging nozzle shall be capable of producing a fine fog mist that will increase the relative humidity of the air just above the fresh concrete surface without accumulating any water on the concrete. The fogging equipment shall be mounted behind the roller and pan of finishing machine or on a separate foot bridge. Controls shall be designed to vary the volume of water flow, be easily accessible and immediately shut off the water when in the off position. Hand held fogging equipment will not be allowed.

SECTION 1104. CEMENT OR POZZOLANIC AGGREGATE MIXTURE EQUIPMENT

1104.01 Mixing Plant. The cement or pozzolanic aggregate mixture plant shall be a batch or continuous type mixing plant. The plant units shall be so designed, coordinated, and operated that they will produce mixtures within the tolerances specified. The plant units shall meet the following requirements.

(a) General. All plants shall be approved by the Department before production begins. Plants not meeting the conditions herein specified may, upon request, be granted a conditional waiver to operate, provided satisfactory evidence is presented that the required modifications are in progress. This conditional waiver will be terminated on November 1 of the year in question and shall not be renewed for any succeeding year.

(b) Safety, Calibration, Inspection Requirements. The plant shall be equipped with safe, unobstructed walkways and stairways, to all sampling points and the mixer platform. Accessibility to the top of the truck bodies shall be provided by a platform or other suitable device. All gears, pulleys, chain sprockets and other dangerous moving parts shall be equipped with guards. Suitable devices shall be provided to enable the Engineer to obtain samples, raise scale calibration equipment, sampling equipment or other equipment from the ground to points of sampling.

(c) Laboratory. Each plant shall be provided with a laboratory, equipped to perform such tests as are necessary for quality control or assessment of the mixture. This laboratory shall be located in the same building as the plant operator, or in a separate building located within 200 ft (60 m) of the plant operator.

Art. 1104.01 Cement or Pozzolanic Aggregate Mixture Equipment

Each laboratory shall be provided with adequate lighting, heating, air conditioning, electrical outlets (110 V service), running water, and a telephone. Furnishings shall include a desk, chair, sink and 3 x 3 x 10 ft (0.9 x 0.9 x 3 m) work bench. Safety and sanitary facilities, including fire extinguisher, first-aid equipment and toilet facilities shall be available on the premises.

The following testing equipment shall be furnished by the producer as part of the laboratory facilities:

1 balance capacity of 0-2500 g complete with appropriate weights
1 set of sieves, 8 in. (200 mm) diameter, consisting of the following sizes:

1 1/2 in. (37.5 mm), 1 in. (25.0 mm),
1/2 in. (12.5 mm), 3/8 in. (9.5 mm),
No. 4 (4.75 mm), No. 8 (2.36 mm),
No. 10 (2.00 mm), No. 40 (425 µm),
No. 200 (75 µm), complete with pan and cover.

1 mechanical sieve shaker and timer.
1 oven with controllable temperature from 73 ± 2 ºF to 230 ± 9 ºF (23 ± 1 ºC to 110 ± 5 ºC)
1 small sample splitter, riffle type, complete with pans.
1 large sample splitter, riffle type, complete with pans.
1 compaction base as required in AASHTO T 180, Article 4.2.

(d) Storage Facilities. Sufficient space shall be provided for storage of each ingredient material type. If necessary to prevent the intermixing of the different materials in adjacent stockpiles, suitable partitions shall be used between the stockpiles. All aggregates shall be kept separated until they are fed in their proper proportions onto a belt conveyor. Aggregates shall be handled in such a manner as to prevent contamination and degradation. Lime, cement, or fly ash shall be stored separately in such a manner that caking, cementing and bulking due to moisture will be minimized prior to introduction into the mix. Storage bins, silos or compartments shall be equipped with warning devices at the lower 1/4 points, which will visually or audibly alert the operator, during production, of a low level condition. A scalper or other device that will remove large lumps of clay, aggregate or fly ash shall be installed at the top of fly ash and aggregate bins.

(e) Crane or End Loader. The crane used in stockpiling the aggregates or conveying the aggregates to the aggregate feeders shall be in good mechanical condition. When compartment aggregate bins are used, the width of the crane bucket shall be not more than one-half the minimum width of the top of the bin compartments, and the maximum length of the bucket when fully open shall be at least 1 ft (300 mm) less than the length of the top of the bin compartment or extensions.

When an endloader is used to charge bins, the maximum discharge width of the bucket shall be 2 ft (600 mm) less than the width of the top of the bin.

(f) Calibration/Calibration Checks of Lime, Fly Ash, Cement, and Aggregate Feeds. Initial calibration of aggregate and/or fly ash shall be accomplished separately, by weighing truckload increments discharged through the mixer. Provision shall be made for diversion of lime in smaller increments acceptable to the Engineer, into appropriate test weight containers, prior to introduction into the mixer.

Calibration checks during production may be performed in smaller quantities, acceptable to the Engineer, of each or all components. Plants equipped with weight belts, for any or all mix ingredients, will require diversion and/or separate weighings of ingredients only during initial calibration, unless required as a result of scale repair or readjustment. Feeders for each ingredient shall be equipped with revolution counters, mechanically connected to a shaft. Calibration and spot checks of all components shall be performed under normal operating conditions of belt speed, and bin or silo head.

The plant shall be equipped to handle and weigh test weight samples and containers. Platform scales of capacity up to 350 lb (160 kg), for weighing lime and check calibration samples shall be of certified accuracy, or otherwise checked for accuracy in the presence of the Engineer using 50 lb (25 kg) test weights. The Contractor (producer) shall also provide truck scales of certified accuracy for weighing of truckload increments.

(g) Proportioning of Lime, Fly Ash, Cement and Aggregate. The plant shall be equipped with accurate means of feeding, by weight (mass) or volume such amounts of lime, fly ash, cement and aggregate(s) as are required by the mixing formula and within those tolerances specified for pozzolanic aggregate and cement aggregate mixtures. If proportioned volumetrically, each ingredient bin or compartment shall have an accurately controlled gate which shall be bolted or otherwise fixed in position during plant operation. If proportioned by weight (mass), each ingredient feed shall be mechanically or electrically controlled so as to automatically maintain present feed rates.

Provisions shall be made so that complete malfunction of any single component feed will initiate an audible or visual warning to the operator until such deficiency is corrected. Warning override shall be effected only for the purpose of mixer clean-out during plant operation.

(h) Mixing Water. Water may be proportioned either by weight or volume. An appropriate indicator reading in gal/min (L/min) or lb/min (kg/min) visible to the operator shall continuously indicate the rate at which water is being discharged into the mixture.

(i) Mixer. The plant shall include a continuous or batch mixer capable of producing a uniform mixture within the job-mix tolerances. Continuous mixers which discharge directly into trucks shall be equipped with discharge/surge hoppers large enough to permit changing trucks without shutting down the plant.

Mixers discharging into surge silo transfer conveyors or elevators will not be required to have discharge hoppers. Mixer paddles shall be adjustable or

reversible, to advance or retard mixture flow. If, in the opinion of the Engineer, adequate mixing is not being obtained, the Engineer may require that an adjustable baffle or dam, which can be locked or bolted in position, shall be installed at the discharge end of the mixer. The mixer shall have attached, a manufacturer's plate giving the net volumetric contents of the mixer at several depths.

(j) Platform Truck Scale for Weighing Cement or Pozzolanic Aggregate Mixtures. Cement or pozzolanic aggregate mixtures shall be measured on platform scales according to Article 1102.01(a)(9).

SECTION 1105. PAVEMENT MARKING EQUIPMENT

1105.01 Thermoplastic. The material shall be applied to the pavement by an extrusion method where one side of the shaping-die is the pavement or by means of an extended ribbon. If used, the shaping-die should be equal to the width of the line specified in the plans. The method used shall produce sharp edges on both sides and square ends on each stripe. The use of pans, aprons, or similar devices to prevent die overruns will not be permitted.

The Contractor shall provide an accurate temperature measuring device capable of measuring the pavement temperature prior to installation of the thermoplastic and the temperature of the molten thermoplastic material immediately after it is applied.

(a) Truck-Mounted. The equipment shall be permanently mounted on a truck of sufficient size and stability with an adequate power source to insure smooth, straight application and capable of maintaining a continuous operating speed of at least 3 mph (5 km/hr). The truck shall be equipped to carry a minimum of 4,000 lb (1,800 kg) of molten thermoplastic. The mounting shall allow the extrusion equipment to accurately follow road irregularities and produce lines of uniform dimensions. The equipment shall have a metering device to register the accumulated installed quantities for each gun, each day. Each vehicle shall include at least one operator who shall be a technical expert in equipment operations and thermoplastic application techniques. Certification of equipment shall be provided at the preconstruction conference.

The application equipment shall be capable of automatically placing intermittent and continuous lines of the various widths and colors of pavement marking lines specified.

(b) Hand-Operated. The Engineer may permit the use of a hand-operated machine for those locations where only a limited quantity of lane and edge lining is required. Words, symbols, and lines other than edge lines may be placed with a hand-operated machine capable of containing a minimum of 125 lb (55 kg) of molten material. For the purpose of these specifications, "hand-operated" shall also include any riding units not considered as "truck-mounted".

1105.02 Epoxy. The epoxy pavement marking compounds shall be applied through machinery designed to precisely meter the two components in the ratio of 2:1. This equipment shall produce the required amount of heat at the mixing head and gun tip and maintain those temperatures within the tolerances specified. This machinery shall also have as an integral part of the gun carriage, a high pressure air spray capable of cleaning the pavement immediately prior to the marking application.

The equipment shall be capable of spraying both yellow and white epoxy, according to the manufacturer's recommended proportions and be mounted on a truck of sufficient size and stability with an adequate power source to produce lines of uniform dimensions and prevent application failure. The truck shall have at least two epoxy tanks each of 110 gal (415 L) minimum capacity and be equipped with hydraulic systems and agitators. It shall be capable of placing stripes on the left and right sides and placing two lines on a three-line system simultaneously with either line in a solid or intermittent pattern, in yellow or white, and applying glass beads by the double drop pressurized bead system at a rate of 10 lb/gal (1.2 kg/L). All guns shall be in full view of operators at all times. The equipment shall have a metering device to register the accumulated installed quantities for each gun, each day. Each vehicle shall include at least one operator who shall be a technical expert in equipment operations and epoxy application techniques. Certification of equipment shall be provided at the preconstruction conference.

SECTION 1106. WORK ZONE TRAFFIC CONTROL DEVICES

1106.01 Signs. Sign faces shall consist of retroreflective sheeting with the appropriate screened message. The retroreflective sheeting shall consist of glass spherical lens elements or plastic micro-prismatic elements covered with a transparent plastic film having a smooth, sealed surface, except that a rectangular pattern may be embossed into the film. The sheeting shall be weather resistant.

At the time of manufacturing, the retroreflective sheeting shall have the following initial minimum coefficient of retroreflection expressed as average candelas/foot candle/sq ft (candelas/lux/sq m) of material. Measurements shall be conducted according to ASTM E 810.

Initial Minimum Coefficient of Retroreflection candelas/foot candle/sq ft (candelas/lux/sq m) of material				
Color	Observation Angle = 0.2 degree Entrance Angle =		Observation Angle = 0.5 degree Entrance Angle =	
	-4 degrees	+30 degrees	-4 degrees	+30 degrees
Red	45.0	25.0	15.0	10.0
Silver/White	90.0	40.0	41.0	21.0
Yellow	60.0	30.0	25.0	13.0
Fluorescent Orange	100.0	30.0	40.0	15.0

The sheeting color shall conform to the appropriate standard color tolerance chart issued by the U.S. Department of Transportation, Federal Highway Administration. Orange signs shall be fluorescent orange in color.

The sheeting surface shall be smooth and flat, easily cleaned, have satisfactory wet performance, and exhibit an 85 degree gloss-meter rating of not less than 40 when tested according to the Test for Specular Gloss, ASTM D 523. The sheeting surface shall be readily processed and compatible with recommended transparent and opaque process inks and show no loss of the color coat with normal handling, cutting, and applications.

Sign sheeting shall be mounted on materials such as aluminum, rigid plastic, or exterior grade plywood. Signs utilizing a base of fabric, fiberboard, or other highly flexible or frangible material will not be permitted, except signs having a reflective sheeting face bonded to a durable plastic or fabric base will be permitted, (a) in work zones with posted speeds above 45 mph (70 km/hr) when workers are present to maintain the devices and (b) in all work zones having posted speeds of 45 mph (70 km/hr) or less.

Specific requirements for various signs shall be as follows.

(a) Work Zone Speed Limit Signs. Work zone speed limit sign assemblies shall be as shown on the plans. The individual signs that make up an assembly may be combined on a single panel.

(b) Flagger Traffic Control Paddle. The "STOP" face shall consist of white letters and border on a red background. The "SLOW" face shall consist of black letters and border on a fluorescent orange background. Areas outside sign borders shall be light blue or black. The portion of the staff within the sign face shall match the sign colors.

The staff may consist of two sections joined by a coupling.

1106.02 Devices. Work zone traffic control devices and combinations of devices shall meet the requirements of the National Cooperative Highway Research Program (NCHRP) Report 350 for their respective categories. The categories are as follows.

Category 1 includes small, lightweight, channelizing, and delineating devices that have been in common use for many years and are known to be crashworthy by crash testing of similar devices or years of demonstrable safe performance. These include cones, tubular markers, flexible delineators, and plastic drums with no attachments. Category 1 devices shall be crash tested and accepted or may be self-certified by the manufacturer.

Category 2 includes devices that are not expected to produce significant vehicular velocity change but may otherwise be hazardous. These include drums and vertical panels with lights, barricades, and portable sign supports. Category 2 devices shall be crash tested and accepted for Test Level 3.

Category 3 includes devices that are expected to cause significant velocity changes or other potentially harmful reactions to impacting vehicles. These include

crash cushions (impact attenuators), truck mounted attenuators, and other devices not meeting the definitions of Category 1 or 2. Category 3 devices shall be crash tested and accepted for either Test Level 3 or the test level specified.

Category 4 includes portable or trailer-mounted devices such as arrow boards, changeable message signs, temporary traffic signals, and area lighting supports. Currently, there is no implementation date set for this category and it is exempt from the NCHRP 350 compliance requirement.

The Contractor shall provide a manufacturer's self-certification letter for each Category 1 device and an FHWA acceptance letter for each Category 2 and Category 3 device used on the contract. The letters shall state the device meets the NCHRP 350 requirements for its respective category and test level, and shall include a detailed drawing of the device. The set-up and use of certified/accepted devices shall be the same as that described in the letter.

At the time of manufacturing, the retroreflective sheeting on devices shall have the following initial minimum coefficient of retroreflection. Measurements shall be conducted according to ASTM E 810. The sheeting color and surface shall be according to Article 1106.01.

Initial Minimum Coefficient of Retroreflection candelas/foot candle/sq ft (candelas/lux/sq m) of material				
Color	Observation Angle = 0.2 degree Entrance Angle =		Observation Angle = 0.5 degree Entrance Angle =	
	-4 degrees	+30 degrees	-4 degrees	+30 degrees
Silver/White	250.0	100.0	95.0	50.0
Fluorescent Orange	100.0	30.0	40.0	15.0

Only the name and telephone number of the agency, Contractor, or supplier may be shown on the non-retroreflective surface of devices. The letters and numbers shall be a non-retroreflective color and a maximum of 2 in. (50 mm) in height.

Devices shall also be constructed as shown on the plans and according to the following.

(a) Lights. Lights shall meet the requirements of the Institute of Transportation Engineers Standard for Flashing and Steady-Burn Barricade Warning Lights. Lights are classified as follows.

Type A - Low intensity flashing
Type B - High intensity flashing
Type C - Steady burning

Lights shall consist of a metal or plastic case, solid state electrical circuit, and head. Lights shall be maintained so as to be visible on a clear night from a distance of 3000 ft (900 m). Type B lights, when required for daylight operations, shall be maintained so as to be visible on a sunny day from a

distance of 1000 ft (300 m) when viewed without the sun directly on or behind the light.

(1) Internal Power (Batteries). The batteries shall be provided by the Contractor but shall not be installed until the light is ready to be used. The light shall be constructed so when the batteries are installed, the terminals are on top of the battery. The batteries shall be contained within the case. The battery terminals shall be either plug or spring type. All electrical connections shall be of non-corrosive material.

(2) External Power. When external power is supplied, all power connections shall be hermetically sealed. The method of installing these lights shall be approved by the Engineer. There shall be an isolated fuse for each light. The fuse shall be located near the pavement edge between the light and the power source and shall be installed so that if one light is damaged, causing a short circuit, all lights will not be extinguished. In all cases, an additional emergency power supply shall be present for operation in the event of power failure. A portable generator may be used as a primary or secondary power source.

(3) Case. The case for the battery shall be constructed of aluminum, galvanized steel, or plastic of an orange, white, or metallic color. The case shall have a vandal-proof fastener on either or on both the side and back, suitable for mounting on barricades or signs. The case shall be weatherproof.

(4) Photoelectric Cell. All Type A and C lights shall be equipped with a switching circuit activated by a photoelectric cell. Type B lights may also be equipped with a photoelectric cell when 24-hour operation is not required in the contract.

(5) Testing and Marking. All lights shall be tested and certified as meeting these requirements by an independent laboratory. Two copies each of the full testing report and certification shall be provided to the Engineer. The report shall specify the lens manufacturer and part number, the circuit manufacturer and part number, the bulb number, and the minimum operating voltage at which the unit meets the intensity requirements of these Specifications. Each light shall be plainly and permanently marked with the type, manufacturer's name, and model number.

(b) Cones. Cones shall be orange and constructed of a durable material able to withstand abuse by vehicular traffic. The minimum weights for the various cone heights shall be 4 lb for 18 in. (2 kg for 450 mm), 7 lb for 28 in. (3 kg for 700 mm), and 10 lb for 36 in. (5 kg for 900 mm) with a minimum of 60 percent of the total weight in the base. Reflectorized cones shall have two white bands.

(c) Type I, II, and III Barricades, Vertical Barricades, and Vertical Panels. Barricades and vertical panels shall have alternating white and fluorescent orange stripes sloping downward at 45 degrees toward the side on which

traffic will pass. Barricade stripes shall be 6 in. (150 mm) in width on barricades rails 36 in. (900 mm) or greater in length and 4 in. (100 mm) in width on barricades barricade rails less than 36 in. (900 mm) in length. Type I and Type II Barricades shall be striped on both sides. Type III Barricades shall be striped on both sides where traffic approaches from either direction. Vertical panels placed on the outside of curves shall be striped on both sides. The predominant color for other barricade components shall be white, orange, or silver.

The face of the barricade rails may be sloping or vertical. Nominal lumber dimensions may be used to satisfy wooden barricade component dimensions.

(d) Direction Indicator Barricades. The top panels shall be fluorescent orange and shall be 12 x 24 in. (300 x 600 mm). The black indicator arrow on the top panel shall be 21 in. (530 mm) long with a 9.5 in. (240 mm) wide arrow barb and 3.5 in. (90 mm) wide arrow shaft. The bottom panels shall be 8 x 24 in. (200 x 600 mm) with alternating white and fluorescent orange stripes sloping downward at 45 degrees toward the side on which traffic will pass.

(e) Drums. Drums shall be nonmetallic and shall have closed tops. Drums may be slightly conical in shape and may have one or more flat surfaces to minimize rolling when hit. Drums shall be weighted in a manner approved by the manufacturer so they are not moved by wind or traffic.

Drums shall have alternating white and fluorescent orange horizontal, circumferential stripes. There shall be at least two white and two fluorescent orange stripes on each drum. If non-reflective spaces are left between the white and fluorescent orange stripes, they shall be no more than 2 in. (50 mm) in width. All non-reflectorized portions of the drums shall be orange.

(f) Flexible Delineators. Flexible delineators shall be designed to bend under repeated impacts and return to an upright position without damage to the impacting vehicle or the delineators. The delineators shall be readily removable from the bases to permit field replacement.

The delineators shall be orange in color having two white and two fluorescent orange bands.

(g) Truck Mounted Attenuators. The attenuator shall be an approved unit that has been successfully crash tested with vehicles weighing 2200 to 4800 lb (1000 to 2200 kg) and impacting the unit at 45 mph (70 km/h). The vehicle to which the truck mounted attenuator is attached shall have a minimum gross vehicle weight rating of 27,000 lb (12,250 kg).

(h) Arrow Boards. Arrow boards shall be rectangular, of solid construction, and finished with non-reflective flat black. The boards shall be mounted as shown on Standard 702001. Remote controls shall be provided with roof mounted arrow boards.

Arrow boards shall have the capability of the following mode selections: (1) left or right flashing shaft with arrow point; (2) flashing shaft with double arrow points; and (3) caution. The arrow point shall be composed of at least five lamps at an angle of 35 to 60 degrees measured from the horizontal shaft which shall be composed of at least three lamps. Shafts in the double arrow point mode shall be composed of at least two lamps for Type A units and three lamps for Type B and C units. The caution mode shall consist of four or more lamps, arranged in a pattern which will not indicate a direction. The lamps or lenses shall be recess mounted or alternately equipped with an upper hood of not less than 180 degrees, and the color emitted shall be yellow. The lamps shall be 12 V, water proof units, consisting of LED, Halogen, or sealed incandescent beams, spaced so as to substantially fill the board. Lamps shall be capable of a minimum of 50 percent dimming from their rated voltage. The flashing rate shall not be less than 25 nor more than 40 flashes per minute. Minimum lamp “on” time shall be 50 percent (no lamps shall remain illuminated during "off" time). All units shall have a permanently mounted voltmeter indicating the voltage available to the lamps. Trailer mounted units shall be equipped with a minimum of two indicator lamps on the near side of the arrow board.

Requirement	Arrow Board Type		
	A	B	C
Minimum Lamp Size	PAR 36	PAR 36	PAR 46
Minimum Number of Lamps	12	13	15
Minimum Legibility Distance: [1/]			
miles	1/2	3/4	1
meters	800	1200	1600

1/ Minimum legibility distances are those at which the arrow board can be comprehended by a driver on a sunny day or clear night.

The power to operate the arrow board shall be supplied from self-contained batteries, (with or without a solar panel generator), a vehicle’s electrical system, a gasoline or diesel fueled generator, or an external power source. Where batteries are used as the primary power source, they shall be capable of providing sufficient voltage, between charging, to each of the lamps for a period of at least 72 continuous hours of operation, in any mode at full daylight intensity. Units utilizing gasoline or diesel fueled generators or an external power source shall be equipped with storage batteries wired so the unit will automatically switch to battery power in the event of failure of the primary power source. The batteries shall be capable of providing sufficient capacity to the lamps for at least three continuous hours of operation in any mode at full daylight intensity.

Where an external power source is used, the cable placement shall meet the approval of the Engineer, and all electrical codes applicable to the area shall be observed. When greater than 24 V is supplied externally, the service cable shall be fused at a location sufficiently removed from the unit so as to leave no live wires exposed at or near the unit in the event of a vehicular collision.

Trailer-mounted units shall be equipped with a photoelectrically operated switch capable of varying the lamp voltage from 6 V for nighttime use to 12 V for daylight use. This switch shall not be capable of manual operation. Failure of this switch shall cause the lamps to operate in the dim mode (6 V) only. Roof-mounted units may be equipped with a manually operated voltage control switch.

(i) Portable Changeable Message Signs. The sign(s) shall be trailer mounted. The message panel shall be at least 7 ft (2.1 m) above the pavement, present a level appearance, and be capable of displaying up to eight characters in each of three lines at a time. Character height shall be 18 in. (450 mm).

The message panel shall be of either a bulb matrix or disc matrix design controlled by an onboard computer capable of storing a minimum of 99 programmed messages for instant recall. The computer shall be capable of being programmed to accept messages created by the operator via an alpha-numeric keyboard and able to flash any six messages in sequence. The message panel shall also be capable of being controlled by a computer from a remote location via a cellular linkage.

The message panel shall be visible from 1300 ft (400 m) under both day and night conditions. The letters shall be legible from 750 ft (250 m).

The sign shall include automatic dimming for nighttime operation and a power supply capable of providing 24 hours of uninterrupted service.

(j) Sign Trailers. Small, lightweight trailers may be used as temporary supports for construction and maintenance signs where post mounted signs are not required by the Highway Standards. The trailer, exclusive of signs, flashing light, and batteries, shall be no more than 300 lb (135 kg) and shall not be fabricated with heavier than 3 x 3 in. (75 x 75 mm) angles, 2 1/2 in. (63 mm) diameter pipes, or 3 x 2 in. (75 x 50 mm) rectangular tubing. The rim size of the wheels should not exceed 12 in. (300 mm). Automotive or truck rear axle assemblies with differential housings shall not be used. In the erected position, the tires may rest on the ground or be elevated with the bottom of the tires no greater than 6 in. (150 mm) above the ground. No weights other than sandbags shall be used and any sandbag or large batteries for the flashing lights shall rest no higher than 12 in. (300 mm) above the ground. Wheel chocks other than sandbags shall not be used. The tongue may be pinned to the ground (or a paved area if approved by the Engineer) to reduce wind-induced rolling. Such a pin shall be designed to readily pull or break in the event of a vehicular impact. The method of pinning shall be approved by the Engineer.

Each end of the rear rail of the trailer shall be equipped with a 3 in. (75 mm) diameter or equivalent red reflector.

1106.03 Temporary Rumble Strips. The rumble strip shall be black in color and formed of high strength polycarbonate. The strip shall be of one-piece construction with two channels on the underside for flexibility and proper adhesive

bondage. The channels shall be interconnected at four or more locations to permit the bonding material to flow from one channel to the other. There shall be at least six weep holes through one or both channels to the upper surface of the strip and at least four through the leading edge of the strip to prevent air voids between the strip and the bonding material.

The rumble strip shall be capable of supporting a load of 6000 lb (2700 kg). The load capacity shall be determined by placing a strip over the open end of a 1 in. (25 mm) high vertically-positioned hollow metal cylinder having an internal diameter of 3 in. (75 mm) and a wall thickness of 1/4 in. (6 mm). The load shall be applied slowly through a 1 in. (25 mm) diameter by 1 in. (25 mm) high metal rod centered on the top flat portion of the strip. No weep holes shall be in the compression area. Breakage or significant permanent deformation of the strip shall constitute failure. Other similar designs may be used with the approval of the Engineer.

APPENDIX A

METRIC UNITS OF MEASURE

Unit	Name	Symbol	Note
Length	meter	m	
Area	square meter hectare	sq m ha	 (1 ha = 10,000 sq m)
Volume	cubic meter liter	cu m L	 (1 L= 1000 cu cm)
Mass	gram metric ton	g metric ton	 (1 metric ton = 1000 kg)
Density	kilogram / cubic meter	kg/cu m	
Force	Newton	N	(N = kg m/s^2)
Pressure, Stress	Pascal	Pa	(Pa = N/sq m)
Energy, Work	Joule	J	(J = N m)
Torque	Newton meter	N m	
Power	watt	W	(W = J/s)
Speed	meters / second kilometers / hour	m/s km/hr	
Temperature	degrees celcius	ºC	

Prefixes		
nano (n)	10^{-9}	one billionth
micro (μ)	10^{-6}	one millionth
milli (m)	10^{-3}	one thousandth
centi (c)	10^{-2}	one hundreth
deci (d)	10^{-1}	one tenth
deca (da)	10^{1}	ten
hecto (h)	10^{2}	one hundred
kilo (k)	10^{3}	one thousand
Mega (M)	10^{6}	one million
Giga (G)	10^{9}	one billion

APPENDIX B

ENGLISH TO METRIC CONVERSIONS

Unit	English	x	Conversion Factor	=	Metric
Length	in.		25.4		mm
	ft		0.3048		m
	mile		1.6093		km
Area	sq in.		645.2		sq mm
	sq ft		0.0929		sq m
	sq yd		0.8361		sq m
	acre		0.4047		ha
Volume	cu in.		16387.1		cu mm
	cu yd		0.764555		cu m
	gallon		3.7854		L
Mass	ounces		28.3495		g
	lb		0.45359		kg
	kip (1000 lb)		0.45359		metric ton
	ton		0.9072		metric ton
Mass/area	ounces/sq yd		0.0339057		kg/sq m
	lb/sq ft		4.8824		kg/ sq m
	lb/sq yd		0.5425		kg/ sq m
	lb/acre		1.1208		kg/ha
	ton/acre		2.2417		metric ton/ha
Density	lb/cu ft		16.01894		kg/cu m
	lb/cu yd		0.5933		kg/ cu m
Force	pound		4.44822		N
	kip		4.44822		kN
Pressure, Stress	lb/sq ft		47.8803		Pa
	kip/sq ft		47.8803		kPa
	psi		6894.76		Pa
	ksi		6894.76		kPa
Energy, Work	foot pound		1.35582		J
Torque	foot pound		1.35582		N m
Power	hp		745.7		W
Speed	mph		1.6093		km/hr
Temperature	(°F - 32)/1.8 = °C				