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Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

Reported by ACI Committee 304

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Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

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American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

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Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

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David A. Burg
Chair

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[*]Subcommittee Chair.

This guide includes a short history of and information on the basic design and operation of equipment, frequently called mobile mixers, used to produce concrete by volumetric measurement and continuous mixing (VMCM). Definitions, applications, and quality assurance testing are discussed. The use of this equipment is compared with weigh-batch-mixing equipment to highlight some of the limited differences.

Keywords: batcher; continuous mixer; flowing (self-consolidating) concrete; fresh concrete; grout; high-early-strength concrete; latex; mixer; no-fines (pervious) concrete; overlay; precast concrete; shotcrete.

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ACI 304.6R-09 supersedes ACI 304.6R-91 and was adopted and published March 2009.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

This document offers guidance on volumetric-measurement and continuous-mixing (VMCM) concrete production. The original and most common use of VMCM equipment is as mobile (either truck- or trailer-mounted) equipment. Because of its compact size, ability to produce mixed concrete, and versatility, a significant number of stationary units have been produced. This configuration provides a free-standing base and is typically powered by electrical circuits normally found in a precast plant or other industrial facility. Unless specifically noted, the information in this document applies to all VMCM equipment.

1.2—Scope

This guide contains background information to be considered when using the VMCM method. A discussion of other types of continuous-measurement equipment (conveyor belt scales or weigh-in-motion scales) is outside the scope of this report.

1.3—History

Volumetric measurement and continuous mixing have a long history in the production of concrete. For many years, the concept of “one shovel of cement, two shovels of sand, and three shovels of stone” was used to produce concrete. Patents on continuous mixers date back at least to 1913. It was not until volumetric measurement and continuous mixing were successfully combined in the early 1960s that general field use of this type of equipment began. The first commercial unit was delivered in 1964. Because of the detail of original patents, there was only one manufacturer of VMCM units until the early 1980s, when other manufacturers began to offer this type of equipment for concrete production.

By the mid-1970s, there were over 4000 VMCM machines in operation in the United States that were generally used to produce small volumes of concrete. During the late 1970s and early 1980s, specialty concretes needed for bridge-deck renovation and highway repair, which were difficult to produce in conventional transit mixers, were produced successfully with VMCM equipment. This application gave the equipment credence by proving that it could consistently produce close-tolerance, high-quality concrete. VMCM equipment was previously thought to be limited to producing special mixtures or small volumes; however, VMCM may be suitable for almost any concrete requirement.

Standards activities related to concrete produced by VMCM equipment have been increasing as the field units increase. In 1971, ASTM developed C685, and now maintains ASTM C685/C685M. The American Association of State Highway and Transportation Officials covers VMCM equipment in M 241. In 1993, ACI published ACI 548.4, “Standard Specification for Latex Modified Concrete (LMC) Overlays,” which lists mobile mixers as the equipment used to produce this product, and designates ASTM C685/C685M as the standard by which these units are defined. In 1999, a group of VMCM equipment manufacturers approached the National Ready Mixed Concrete Association (NRMCA) for assistance in forming the Volumetric Mixer Manufacturer Bureau (VMMB). The VMMB was formed, and in 2001 published VMMB 100-01, which defines the volume of ingredients needed to produce a cubic yard of concrete, and references ASTM C685/C685M uniformity requirements as the measure of accuracy in this type of equipment.

CHAPTER 2—DEFINITIONS

measuring, volumetric—dispensing an ingredient based on volume, either in discrete quantities or by continuous flow.

mixing, continuous—producing concrete by continuously blending ingredients in fixed proportions. The discharge of the concrete mixture may be started or stopped as required.

CHAPTER 3—EQUIPMENT

3.1—Materials storage and measurement

Measurement of material by volume can be accomplished by a variety of means. Rotary vane feeders (both horizontal and vertical axis), screw conveyors (both adjustable and fixed speed), drag chains, calibrated gate openings, variable-volume sliding compartments, and vibrating plate feeders have been used to measure quantities of dry ingredients. Liquids can be introduced by air pressure, pumps, or cylinders, with the flow controlled by valves or timers and measured by flow meters. Whichever methods of material metering are used, they should be consistent to ensure the production of a proper mixture. Documents produced by the equipment manufacturers should be referenced for operating details of the various types of equipment. Cement, water, and admixtures are stored in separate containers and are measured separately. Fine and coarse aggregates are stored either separately or combined. If aggregates are stored and used in a combined state, they should be accurately preblended, and particular care should be taken to avoid segregation.

A meter or other indicator on the equipment records the amount and the rate of introduction of cement into the mixture, and this rate serves, directly or indirectly, to control the rate at which other ingredients are added. All systems are interconnected so that once they are calibrated and set to produce a specific concrete mixture, all ingredients are simultaneously and continuously measured into the mixer. This interconnecting allows either continuous or intermittent operation of the system to accommodate the quantities of the concrete needed. These interconnections should not be confused with the interlocks typically found in weigh-type batch plants. VMCM equipment is designed to allow the relative proportions of ingredients to be changed rapidly to vary the concrete mixture as required. Because the mixing chamber only holds approximately 4 ft^3 (0.10 m^3), such changes can be made with little or no waste. Typical VMCM units carry enough materials to produce 6 to 10 yd^3 (4.5 to 8 m^3) of concrete (Fig. 3.1). This limitation is based on axle loading limitations. Production of larger volumes of concrete or high rates of production will require provisions for recharging the material storage compartments.

3.2—Mixers

Most continuous mixers use an auger rotated in a sloped trough or tube. Materials are introduced at or near the lower end, and the mixed concrete is discharged at the other. This basic principle is the same for all VMCM equipment, although there are many individual variations. Augers are available in different lengths and diameters, can operate at different speeds, and can have continuous or interrupted flights. Troughs may have flexible or rigid bottoms and covered or open tops. The slope of the mixer may be fixed or adjustable. Lowering the trough (which is normally set at about a 15-degree inclination) may reduce the mixing time, while raising the trough may extend it. Mixing time can be adjusted by modifying the mixer angle of inclination, mixer rpm, mixer flighting configuration, throughput rate, or a combination of these. Actual mixing time from input to output is usually less than 20 seconds. Mixing times as long as 45 seconds have been achieved, but this comes at a considerable reduction in production throughput.

With this type of mixer, output is always equal to input, with a relatively small amount of material being mixed at any one time. Thorough mixing is accomplished in a very short time by applying high-shear, high-energy mixing to the

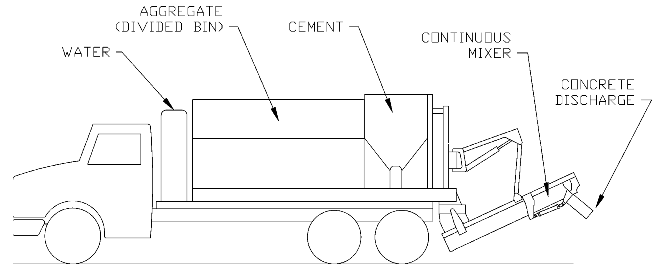


Fig. 3.1—Typical VMCM system.

material. A pivot at the base of most mixers allows them to swing from side to side.

3.3—Equipment condition

All proportioning and mixing equipment should be well maintained in accordance with the manufacturer's instructions. This point cannot be overemphasized. Equipment condition directly impacts the quality of the finished product.

Attention should be paid to the following areas:

- The cement dispenser should be clean and free of any buildup;
- Valves should operate smoothly and not leak;
- Any accumulation of materials on any controlling surface or opening in the system will alter the calibrated flow of materials;
- Mixer augers should not be allowed to wear beyond the manufacturer's recommended limits;
- There should be no buildup of concrete on the mixer auger surfaces;
- Delivery mechanisms should be properly adjusted and kept in good repair;
- There should be no leaks in the hydraulic or air systems;
- There should be no cut or damaged insulation on electrical wires; and
- All covers and guards should be securely in place.

ASTM C685/C685M provides guidance for evaluating mixer uniformity.

CHAPTER 4—OPERATIONS

4.1—General

Volumetric measurement and continuous mixing are suitable for producing almost any concrete with appropriately sized aggregate, provided the equipment is operated with the same attention to detail as would be required to produce concrete by any other means. Most of the present equipment is truck- or trailer-mounted, or at least portable, and typically serves as its own material transport. The portability of the equipment makes it practical to bring the VMCM unit to the placement site, which can be an advantage in many applications. Having the unit on site also allows close control of concrete quality. Several manufacturers offer VMCM equipment designed to be placed in a fixed position in a precast plant or at a job site.

4.2—Production rates

Maximum production rates are dependent on the physical and mechanical characteristics of the VMCM unit. Discharge rates for 100 lb (45 kg) of cement range from

Fig. 4.1—Continuous production with recharging of VMCM unit at job site.

about 6 to 60 seconds. For a concrete with a cement content of 560 lb/yd^3 (330 kg/m^3), these discharge rates imply production rates of approximately 10 to 110 yd^3/hour (8 to 80 m^3/hour). These rates, however, can only be achieved for an extended time if the units are resupplied with materials during production (Fig. 4.1). The manufacturer's rated production rate and cubic yard (cubic meter) capacity are stated on data plates, which are located on ASTM- and VMMB-approved equipment.

4.3—Planning

A review should be made of the project requirements before concrete production. Depending on the application, this may be a quick review by the operator, or a more detailed formal meeting with all parties involved. Review points should include discussion of the following items, which are further covered in Chapter 6:

1. Source and current calibration of all materials to be used;
2. Proper functional controls and settings for the job;
3. Production rates and delivery times;
4. Testing requirements and methods;
5. Availability of testing equipment; and
6. Adequate access on site for operation.

4.4—Materials

The same ingredients used for concrete production should be used to calibrate the unit. All materials should be stored and handled in accordance with accepted concrete practices (ACI 304R). The following additional considerations apply to VMCM equipment:

- The moisture content of the fine aggregate should be carefully controlled to avoid undesirable variations in the mixture;
- Particular care should be taken during loading to avoid spilling materials into the wrong compartments;
- When moist aggregates are preloaded (6 to 8 hours in advance of production), the operator may need to reduce the initial water introduction slightly to maintain the proper slump and compensate for water that has percolated to the bottom of the aggregates;
- Preloaded equipment should be stored inside or covered during inclement weather; and
- Driving loaded equipment long distances over rough roads may compact materials, causing errors in flow rates. If this occurs, it may be necessary to discard a small initial quantity material produced to ensure that proper mixture proportioning is achieved.

4.5—Personnel qualifications

It is essential that personnel responsible for equipment control be knowledgeable in all phases of its use. Control of material proportions is direct and immediate; therefore, operators should also understand the significance of any adjustments made. This also places additional responsibilities on quality control personnel, as any change in the system could possibly adversely affect concrete quality and cost. Personnel involved in operating this type of equipment should have a thorough understanding of the controls and should be acquainted with concrete technology. Personnel authorized to make adjustments of the proportioning controls should have training, certification, or both, from the equipment manufacturer or have at least 4 weeks of on-the-job training with qualified personnel. ACI Concrete Field Testing Technician, Grade I Certification is recommended.

CHAPTER 5—APPLICATIONS

5.1—General

VMCM equipment lends itself to a wide variety of applications. While many of these applications involve relatively low-volume production of concrete (less than 1 yd^3 [0.8 m^3]), some very large jobs in excess of 1000 yd^3 (800 m^3) have also been completed with VMCM equipment. In addition to producing conventional concrete, VMCM equipment is well suited for a number of special applications. Some of these are discussed in the following sections.

5.2—Mixtures with short working times

Concretes made with rapid-setting cements, special rapid-setting admixtures, or polymeric materials have a relatively short working life. Applications include repairs to hydraulic and highway structures, pavement, and precast concrete products. Because VMCM equipment proportions and mixes at the job site, the maximum possible working time is obtained.

5.3—Low-slump mixtures

Some applications require concrete with a very low slump. Because of the positive discharge of a continuous mixer, VMCM equipment can easily produce these mixtures. An application of this type is the low-slump Iowa Department of Transportation high-density overlay (Fig. 5.1). In this case, 1 in. (25 mm) maximum slump is permitted, and no additional water can be added to the concrete. Other applications include slip-form placing, and production of dry shotcrete and pervious concrete mixtures. The efficient mixing action of the continuous mixer is capable of handling all of these applications.

5.4—Latex-modified overlays

Overlays of bridge decks, as well as other structural decks using a latex emulsion additive, are a popular use for VMCM equipment. Job-site control is essential for proper production of this mixture. Properly equipped VMCM equipment is specified as the main acceptable method of production for most DOT bridge deck overlays (Fig. 5.2).

Fig. 5.1—Production and placement of high-density, low-slump bridge overlay concrete with VMCM unit.

Fig. 5.2—Production of latex-modified concrete overlay with VMCM unit.

5.5—Long unloading times

Some applications require relatively small amounts of concrete on a constant basis. Shotcrete and vertical slip-forming are good examples. Changes in concrete properties could occur if a large volume of concrete is held at the job site and discharged over a long period. Dry and wet shotcrete production often fits in this category. VMCM equipment easily produces these mixtures.

5.6—Concrete at remote sites

A VMCM unit is a complete proportioning and mixing system. It can be used as a plant at the job site, thereby eliminating long haul times for ready mixed concrete. In remote areas, this can be very cost effective from both a production and quality standpoint (Fig. 5.3). Units mounted on barges have been used for underwater concrete applications (Fig. 5.4). Configurations to fit on rail cars are used for remote construction and repair of rail lines (Fig. 5.5).

5.7—Making small deliveries

Small orders of ready mixed concrete often require individual trips for each order. These small orders can be consolidated into one trip with a VMCM unit. The unit can go out full and does not need to return until empty (Fig. 5.6). Repair and maintenance of streets and highways where small quantities of concrete are required at multiple stops are easily accomplished using VMCM equipment.

Fig. 5.3—Job-site concrete production with VMCM unit in remote location.

Fig. 5.4—VMCM unit on barge for production of concrete for underwater placement.

Fig. 5.5—Rail-car-mounted VMCM units for concrete production in remote locations.

5.8—Precast operations

VMCM units in precast plants (Fig. 5.7) can provide uninterrupted delivery throughout a large area with rapid control of consistency and workability. Self-consolidating concrete (SCC) has been successfully produced with VMCM equipment. It is recommended that any admixture(s) used to produce SCC are tested to ensure compatibility with

Fig. 5.6—VMCM unit producing small quantities of concrete.

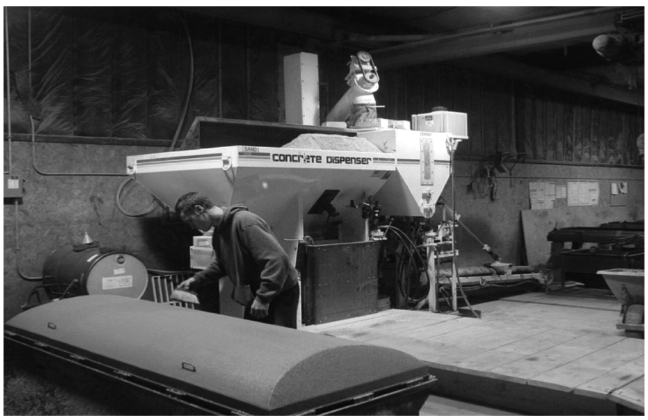


Fig. 5.7—VMCM unit producing concrete in precast concrete facility.

the very short mixing time associated with a VMCM unit. For more information, refer to ACI 237R.

5.9—Hot weather concreting

Concrete is discharged as it is mixed; therefore, hydration takes place after the discharge. The concrete can be in place quickly after mixing; therefore, there is little chance for the concrete to heat up while mixing in transit before placement. No tempering water is required to maintain workability; therefore, the water-cement ratio (w/c) can be controlled more easily.

5.10—Mining applications

Because of their compact size, VMCM units have been customized to fit into mineshafts. These units are typically reduced in height. Units also have been designed as components that bolt together so they could be reassembled in the mine after entering via a standard hoist. Material was then delivered to the unit, and concrete or shotcrete was mixed as needed.

5.11—Grouting and pile filling

Grouting and pile filling often require small volumes over an extended period. Both placement types require that a suitable material be available when the application is ready, and both may require indefinite volumes of material. Retempering, which may be required if large volumes of ready mixed concrete or grout are held waiting at the job site, is not a consideration with VMCM equipment.

Fig. 5.8—Trailer-mounted VMCM unit providing large volumes of controlled low-strength fill material.

5.12—Colored concretes

Many projects require colored concrete. The small mixing auger can be cleaned much more quickly and more thoroughly than full-size batch-type mixers. The vigorous mixing action of the auger-type mixer thoroughly homogenizes the mixture for uniform coloring. Both dry color pigment and color emulsions have been used successfully with VMCMs that have appropriate dispensing equipment.

5.13—Emergency applications

VMCM units may be used as emergency sources of concrete to handle repair situations. A preloaded unit could be held in standby for emergency situations that arise when there is no other source of concrete.

5.14—Controlled low-strength fill

Properly equipped VMCM units have produced large volumes of controlled low-strength fill. Over 28,000 yd^3 (21,000 m^3) were produced and pumped at a major research facility in the United States to stabilize and support a particle accelerator. One VMCM was loaded continuously with all ingredients for a daily production of up to 800 yd^3 (610 m^3) (Fig. 5.8). Cellular (foaming admixture) concrete has been successfully produced using VMCM equipment. The process should be tested before production begins using the particular foam to test the stability of the foaming agent in equipment with a short mixing time.

5.15—Fiber-reinforced concrete

VMCM equipment can produce fiber-reinforced concrete using glass fibers, steel fibers, and poly fibers. Fiber feeders and cutters have been developed to feed these various fibers on a consistent basis.

5.16—Military applications

The three main branches of the United States military and some foreign militaries own VMCM concrete production equipment. A VMCM unit is very mobile. This feature makes it useful for military applications where mobility can be the key to success.

Fig. 5.9—Airfield runway repair using VMCM unit.

The ability of VMCM equipment to produce rapid-setting concrete mixtures has been used by air forces to rapidly repair runways. This allows an airfield to be used as soon as repairs are made (Fig. 5.9).

CHAPTER 6—QUALITY CONTROL AND TESTING

6.1—General

The production of concrete by VMCM is subject to the same rules of quality control as any other concrete production method. The equipment should be clean, well maintained, and operated by experienced personnel. ASTM C685/C685M is the standard specification for concrete made by VMCM methods, and is similar to ASTM C94/C94M for ready mixed concrete. As with any type of batching and mixing equipment, common sense, experienced personnel, and trained inspectors are the best quality assurance tools. Another important specification covering VMCM equipment is VMMB 100-01, which references ASTM C685/C685M.

6.2—Calibration

To ensure production of quality concrete, each volumetric measuring unit should be calibrated for each respective concrete ingredient, following the manufacturer's recommendations and ASTM C685/C685M. The ingredients should be the same as those used in actual concrete production. The measuring devices for aggregates, cement, and dry admixtures are individually calibrated by determining the mass of the discharged ingredient. Devices for measuring liquids such as water, latex modifier (if required), or liquid admixtures, such as air-entraining and chemical admixtures, are calibrated by determining the mass or measuring the volume of the discharged ingredient. The objective of calibration is to coordinate the discharge of all concrete ingredients to produce the proper mixture.

A complete calibration procedure should be conducted:

- For all new equipment;
- When test data indicate that the concrete is not meeting specified performance levels;
- When specified by the purchaser or engineer;
- When major mechanical repairs are performed on the VMCM unit; and
- When a change is made in materials or mixture proportions for which previous calibration data are unavailable.

Complete calibrations should also be accomplished on a periodic basis in addition to the reasons stated previously. Six months or 2500 yd^3 (2000 m^3) of production are suggested as the maximum intervals between calibrations.

An abbreviated calibration to verify cement discharge or a volumetric yield check will verify the accuracy of previous control settings. Such abbreviated calibrations are useful and economical when small quantities of concrete (under 50 yd^3 [40 m^3]) are produced using the same control settings with similar ingredients. Project specifications should clearly define calibration as well as concrete performance requirements, and equipment should be calibrated to meet those requirements. A suggested calibration procedure is included as Appendix A to this report.

6.2.1 *Precalibration checks*—Before initiating any material calibration, it is imperative that a check of the mixer is performed to ensure all components critical to production are functioning properly. At a minimum, checks should be made to ensure that flow control mechanisms are adjusted and the graduated dial/indicator readings match the actual mechanism opening parameters on the VMCM unit. Cement bin vibrators and aeration pads should be functioning properly, and the cement bin should be clean and free from material buildup. Operating speeds should be confirmed and adjusted to optimum operating speeds for that piece of equipment. If a VMCM uses two aggregate bins, bin guides should be straight and should not show signs of wear that would cause problems with consistent material flow. Finally, the mixing auger should be inspected to ensure that it is within wear tolerances and that all blades and paddles are clean and free from buildup. Additional checks may be added by the user based on differences in equipment and project-specific requirements.

6.2.2 *Equipment*—The following equipment is recommended to perform a full calibration:

- A scale with a minimum capacity of 300 lb (135 kg);
- A clean container to catch cement and aggregate discharge;
- A container calibrated in fluid ounces (mL) to catch admixture discharge;
- A container to catch water or other liquid discharge;
- A stopwatch accurate to one-tenth of a second; and
- A container to check volumetric yield (normally a 1/4 yd^3 [0.20 m^3] box).

Tolerances, as stated in ASTM C685/C685M, are:

Cement, mass %	0 to + 4
Fine aggregate, mass %	2 ± 2
Coarse aggregate, mass %	2 ± 2
Admixtures, mass or volume %	3 ± 3
Water, mass or volume %	1 ± 1

6.2.3 *Cement*—The cement discharge system is normally connected directly to the indicator used to determine concrete production quantity. This system also determines the rate at which all other discharge systems should provide materials to the mixer to produce the required mixture. It is necessary to establish the mass of cement discharged for a given register or counter reading as well as the amount discharged in a given time.

When calibrating cement, precautions should be taken to ensure that the aggregate bins are empty or separated from the system, and that all of the discharge is collected. Any carrying mechanisms for the cement should be primed by operating the system until any surface between the storage bin and the collection container that might attract cement becomes coated. The meter register or counter should then be reset to zero, and a minimum of five calibration runs should be made. Sufficient counts and time should be run to discharge a minimum of 100 lb (45 kg) of cement. A minimum of five test runs is recommended to ensure accuracy and repeatability. When calibrating discharge systems, it is preferable to stop the run at a whole number on the discharge indicator rather than attempt to stop at a fixed time or mass.

At the conclusion of each run, the counter reading, time (in seconds), and the gross and tare mass should be recorded. The net mass and mass per counter unit should then be calculated. The mass of cement discharged in 1 minute should also be calculated. From this information, the indicator reading or count representative of the discharge quantity of cement required to produce a cubic yard (cubic meter) of a specific design can be calculated (refer to Appendix A).

6.2.4 *Aggregates*—Aggregate discharge controls should be calibrated to provide the correct proportions in relation to the cement. This can be accomplished by establishing a discharge rate in mass per unit time or mass per counter unit. The required mass of aggregate discharge for either of these units may be calculated and trials made at various control settings until the desired mass is collected. Aggregates should be calibrated individually. This method of trial and error is best used when working with a familiar mixture proportion and similar aggregates.

When the system is being calibrated for several mixtures and with unfamiliar aggregates, it may be useful to plot mass per unit time (or unit count) versus control settings for a minimum of three control settings, with three runs at each setting to ensure accuracy and repeatability. The graph developed can then be used to interpolate the required settings for the various concrete mixtures. Verification runs (yield check) should be made after any such chart is developed.

6.2.5 *Water*—Normally, the control setting for the maximum permitted water is determined for a given time or meter unit on the cement register. The discharge is then collected and measured in a graduated container or the discharged mass is determined to verify the setting. The accuracy of flow meters (gallons [liters] per minute), recording flow meters (total gallons [liters]), or both, should be verified at this time. For each calibration run, the system should be operated at least as long as the discharge time for 100 lb (45 kg) of cement. A minimum of three runs should be taken to ensure accuracy and repeatability. Because there are fewer mechanical operating components involved with the water discharge than with the cement, fewer calibration runs will be necessary.

6.2.6 *Admixtures*—Wet or dry admixture discharge should be calibrated for indicated flow rate versus measured delivery. The flow of each calibrated admixture should be caught in a calibrated receptacle for at least as long as the discharge time of 100 lb (45 kg) of cement. A chart of flow indicator position versus actual flow can be established. As many calibration runs as necessary should be made to meet the specified tolerances. A minimum of three runs should be taken to ensure accuracy and repeatability.

Fig. 6.1—Volumetric yield test being conducted.

6.2.7 *Post-calibration volumetric yield test*—Once calibration is complete, it is recommended that a volumetric yield test be performed. This test serves as a check to ensure that the mixture proportion is correct and that the controls on the VMCM unit are correctly calibrated and set. A suggested procedure to accomplish this test is as follows:

1. All controls should be set to produce the desired mixture.
2. All interlocks should be engaged, and all systems should be charged.
3. All systems should be stopped simultaneously, and the meter register or counter reset.
4. A container of known volume with rigid sides should then be placed under the discharge of the mixer.
5. All systems should then be engaged and started simultaneously until the predetermined count is reached on the counter or indicator, at which point all systems are stopped again.

The count is predetermined based on the known volume of the container; for example, one-fourth of the 1 yd^3 count should be used with a 1/4 yd^3 container, or one-fifth of the 1 m^3 count should be used with a 0.20 m^3 container (Fig. 6.1). Another yield check method using concrete density (unit weight) is detailed in ASTM C685/C685M.

6.2.8 *Preproduction tests*—After calibration, preproduction tests can be made to confirm whether the production mixture proportions meet the requirements of the design mixture proportions, and to provide a reference for production testing. The following minimum tests should be made at this time: air content (ASTM C231 or C173/C173M), slump (ASTM C143/C143M), and unit weight (ASTM C138/C138M). It is also advisable to cast cylinders for compressive strength testing at this time.

6.3—Production testing

Parameters for testing should be established to meet project requirements. Generally, testing for concrete produced using VMCM equipment should follow the same guidelines as for concrete produced by other methods.

Suggested routine tests include: air content (ASTM C173 or C231), slump (ASTM C143/C143M), and density (ASTM C138). Project specifications should include the frequency intervals for these tests. This frequency may vary from one set of tests per unit per day to one set for each load. As with weigh-batched concrete, these tests serve as a quick check for quality control.

It is also good practice to perform a volumetric-yield test on each mixer at least once per week or at intervals of at least 200 yd^3 (150 m^3) of production. The concrete produced for this yield test can often be incorporated directly into the work. The previously mentioned air, slump, and density tests should also be made at this time from concrete obtained at point of discharge. Cylinders or beams for strength tests should be cast at the same time as the other testing as required by the specification. Any other suitable tests may be used at the discretion of the specifier; however, experience and economics dictate that such testing need not be more stringent than that required for weigh-batched concrete.

CHAPTER 7—OPERATIONAL PRECAUTIONS

7.1—General

The volumetric measurement and continuous mixing equipment should be in good condition. All shields and covers should be in place. All controls should operate smoothly and be connected according to the manufacturer's recommendations. All material feed operations should start and stop simultaneously. The cement measuring device should be inspected and cleaned regularly. Indicating meters and dials should be operational and readable. Admixture systems should be checked for proper flow and operation. All filters should be clean and allow full flow of water or other liquids. Aggregate feed systems should be free of any blockage. Checks of the various feeding systems should be carried out according to the manufacturer's recommendations, and as job experience indicates.

7.2—Cold weather concrete

With a mobile VMCM unit, constraints on the size and weight of heating units limit the options for heating the water or the aggregate on the unit. If appropriate, load the unit with preheated water and aggregates to produce quality concrete in cold weather. All aggregates should be free of frozen material, as frozen lumps may affect the metering accuracy. All liquid lines should be protected from freezing, and drained when not in use. Flow meters should be checked for proper operation and protected from damage by freezing liquids. Additional information on cold weather concreting may be found in ACI 306R.

7.3—Hot weather concrete

Using VMCM under hot weather concreting conditions is not greatly different from conventional concrete practice. The general principles as outlined in ACI 305R for maintaining concrete temperatures below specified limits will apply. Because the water and cement contact with VMCM equipment occurs less than 20 seconds before discharge, the problems associated with hot weather and delayed discharge by conventional ready mixed trucks are usually not a concern.

7.4—Aggregate moisture

Because proportioning is done on a continuous basis, it is desirable to supply the machine with aggregates of uniform moisture content. Bulking of fine aggregate is not normally a consideration because the usual moisture content covers a small range where bulking is fairly constant. A yield check is recommended when there is a wide swing in moisture content (5% or more). This check indicates if recalibration is required. Aggregate stockpiles being used to charge VMCM units can be covered to minimize variations in moisture content. It may be necessary to limit the free moisture in aggregate by drying, covering, or both, to meet a low *w/c* requirement when high volumes of liquid additives, such as latex or strongly diluted admixtures, are used, or when low-slump concrete is produced. Maximum allowable water control settings should be established for maximum and minimum anticipated aggregate moisture contents.

7.5—Rapid slump loss due to false set

It has been noted that, with some cements, a rapid slump loss occurs after discharge from the mixer (ACI 225R). The cause is believed to be related to the short mixing time typical with this type of equipment. The problem does not occur often, and a change of cement will normally correct it.

7.6—Use of admixtures

Continuous mixers are high-shear, high-speed mixers. Some admixtures perform differently than might be expected when used with batch mixers. Admixtures that require lengthy mixing times for activation may not perform well in a VMCM. For this reason, the performance of admixtures should be verified by testing for the desired result before actual project placement begins. Unexpected negative performance can usually be corrected by consultation with the admixture and equipment manufacturers. Adjustments can then be made to produce the desired outcome. Experience has shown that these results will remain consistent once the desired result has been verified on a particular piece of equipment.

7.7—Freshly mixed concrete properties

Fresh concrete produced by VMCM equipment behaves slightly differently than ready mixed concrete. Elapsed hydration time at discharge is measured in seconds rather than in minutes. This means that, while the actual setting time (from start of hydration) is the same, the apparent setting time (from time in place) may seem longer. Finally, the apparent slump at discharge is often higher than the measured slump 3 to 5 minutes after discharge. Finishers and inspectors should be made aware of these differences.

CHAPTER 8—REFERENCES

8.1—Referenced standards and reports

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper group if it is desired to refer to the latest version.

American Association of State Highway & Transportation Officials
M 241 Concrete Made by Volumetric Batching and Continuous Mixing

American Concrete Institute
225R Guide to the Selection and Use of Hydraulic Cements
237R Self-Consolidating Concrete
304R Guide for Measuring, Mixing, Transporting, and Placing Concrete
305R Hot Weather Concreting
306R Cold Weather Concreting
548.4 Standard Specification for Latex-Modified Concrete (LMC) Overlays

ASTM International
C94/C94M Standard Specification for Ready-Mixed Concrete
C138/C138M Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Standard Test Method for Slump of Hydraulic-Cement Concrete
C173/C173M Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C685/C685M Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

Volumetric Mixer Manufacturers Bureau
VMMB 100-01 Volumetric Mixer Standards

The above publications may be obtained from the following organizations:

American Association of State Highway & Transportation Officials
444 N. Capitol St. NW Ste. 249
Washington, DC 20001
www.transportation.org

American Concrete Institute
38800 Country Club Dr.
Farmington Hills, MI 48331
www.concrete.org

ASTM International
100 Barr Harbor Dr.
West Conshohocken, PA 19428-2959
www.astm.org

Volumetric Mixer Manufacturers Bureau
900 Spring St.
Silver Spring, MD 20910
www.vmmb.org

APPENDIX A—SAMPLE CALIBRATION PROCEDURE/FORMS

NOTE: This is a suggested calibration procedure that has been used to successfully field calibrate VMCM equipment. The objective of this calibration procedure is to develop flowcharts and graphs that will allow the operator to set the controls so that the desired mix design is produced. The procedures and data on this page focus on the calibration of the cement discharge.

The operator's manual for the particular equipment being calibrated should be consulted and the manufacturer's recommendations followed. All mechanisms must be clean, in good operating condition, and well maintained.

CEMENT CALIBRATION WORKSHEET

UNIT SERIAL # ____________________

OWNER ____________________

CEMENT TYPE ____________________ DATE ________________

CEMENT SOURCE ____________________ LOCATION ________________

CEMENT OUTPUT INDICATOR SETTING __________

TRIAL #	1	2	3	4	5	TOTAL
COUNTS	____	____	____	____	____	A= ____
GROSS WT	____	____	____	____	____	
TARE WT	____	____	____	____	____	
NET WT	____	____	____	____	____	B= ____
TIME	____	____	____	____	____	C= ____

DETERMINE THE COUNTS PER 100 LBS(KG) OF CEMENT

TOTAL POUNDS (KG) (B) __________ DIVIDED BY TOTAL COUNTS (A) ________ =

(D) __________ **LBS(KG) PER COUNT**

100 LBS(KG) DIVIDED BY LBS(KG) PER COUNT (D) __________ = **(E)** ________ **COUNTS PER 100 LBS(KG)**

DETERMINE THE DISCHARGE TIME PER 100 LBS(KG)

TOTAL COUNTS (A) __________ DIVIDED BY TOTAL SECONDS (C) ________ =

(F) __________ **COUNTS PER SECOND**

COUNTS PER 100 LBS (KG) (E) __________ DIVIDED BY COUNTS PER SECOND (F) ________ =

________ **SECONDS PER 100 LBS (KG)**

Notes:

On the first calibration after initial filling of the cement bin it may be necessary to make a number of measurements until all feeding mechanisms are properly charged with cement, and a consistent discharged amount meeting the tolerences required is obtained.

VMCM MIXTURE DESIGN WORKSHEET

UNIT SERIAL # _________
MIXTURE # __________________
STRENGTH __________________

Mixture design for 1 $yd^3(m^3)$:

CEMENT	_________ LBS(KG)	______________	counts per 100 lbs(kg) of cement. (From Cement Calibration Worksheet)
FINE AGG	_________ LBS(KG)	______________	seconds discharge time for 100 lbs(kg) of cement. (From Cement Calibration Worksheet)
COARSE AGG	_________ LBS(KG)		
WATER	_________ GAL. (L)		

1. Determine the count per $yd^3(m^3)$.

The master reference for VMCM equipment is the cement register to which the flow of all ingredients is related. To determine the counts required for 1 $yd^3(m^3)$ divide the cement content by 100 and multiply that quotient by the counts per 100 lbs(kg) as determined from the Cement Calibration Worksheet.

_____________ lbs(kg)/$yd^3(m^3)$/100 X ______________ counts per 100 lbs(kg)= ____________ counts per $yd^3(m^3)$

2. FINE AGGREGATE: Divide the lbs(kg) of fine aggregate per $yd^3(m^3)$ by the counts per $yd^3(m^3)$

NOTE: ENSURE YOU REFER TO THE PROPER GRAPH

___________ lbs(kg) fine aggregate/$yd^3(m^3)$ divided by _________ counts per $yd^3(m^3)$= _________ lbs(kg) per count.

At this point one uses the graph developed for the fine aggregate and locates the lbs(kg)/count on Y axis, then with a straightedge moves horizontally to the right until intersecting with the data line and then vertically down to determine a reference point setting.

FINE AGGREGATE REFERENCE POINT SETTING (from graph) _________

3. COARSE AGGREGATE: Divide the lbs(kg) of coarse aggregate per $yd^3(m^3)$ by the counts per $yd^3(m^3)$

NOTE: ENSURE YOU REFER TO THE PROPER GRAPH.

_____________ lbs(kg) coarse aggregate/$yd^3(m^3)$ divided by _________ counts per $yd^3(m^3)$= _________ lbs(kg) per count.

At this point one uses the graph developed for the coarse aggregate and locates the lbs(kg)/count on the Y axis, then with a straightedge moves horizontally to the right until intersecting with the data line and then vertically down to determine a reference point setting.

COARSE AGGREGATE REFERENCE POINT SETTING (from graph) _________

4. WATER: To determine the maximum allowable water addition rate, it is first necessary to determing the time required to produce 1 $yd^3(m^3)$
Multiply the number of 100 lbs(kg) cement increments in 1 $yd^3(m^3)$ times the discharge time per 100 lbs(kg) of cement.
Refer to the Cement Calibration Worksheet.

_____________ lbs(kg) cement per $yd^3(m^3)$/100 X _________ seconds per 100 lbs(kg) discharge time=

_________ seconds per $yd^3(m^3)$ / (1 min/60 seconds)=

_________ min per $yd^3(m^3)$

Note: One may determine the amount of free water in the aggregates and subtract it from the total mixture design water at the top of this page, thereby calculating a maximum allowable total added water, which is then used in the following calculations.
Divide the total allowable added water by the time in minutes required to produce a $yd^3(m^3)$ of concrete.

_____________ total maximum allowable added water gal.(L)/$yd^3(m^3)$ / ____________ minutes for 1 $yd^3(m^3)$=

_________ **gal./min (LPM) maximum allowable addition rate**

ACI 304.6R recommends that a yield test be conducted. Refer to section 6.2.7.

SUMMARY MIX NUMBER	____________
Counts/$yd^3(m^3)$	____________
Fine aggregate reference point	____________
Coarse aggregate reference point	____________

VMCM MIXER FINE AGGREGATE CALIBRATION WORKSHEET

The purpose of this document is to collect data so that a flow graph for a particular fine aggregate can be developed.
The actual fine aggregate to be used in concrete production must be used.

OWNER ____________________
UNIT SERIAL # ____________________

SOURCE OF FINE AGGREGATE ____________________ DATE __________
TYPE OF FINE AGGREGATE ____________________

1. DISCONNECT CEMENT FEEDING MECHANISM.
2. ENSURE ANY AGGREGATE RETENTION ITEMS ARE ADJUSTED PROPERLY.
3. FOR TWO AGGREGATE BINS, FILL ONLY ONE BIN APPROXIMATELY HALF FULL.
4. ENSURE THE REFERENCE INDICATOR IS PROPERLY ADJUSTED AND CALIBRATED.
5. AFTER A CHANGE IS MADE TO THE METERING DEVICE SETTING, ENSURE ALL RETAINED MATERIAL FROM THE ORIGINAL SETTING IS DISCHARGED.
6. A CALIBRATION IS REQUIRED FOR EACH MATERIAL. IF YOU CHANGE MATERIALS EITHER BY SOURCE OR GRADUATION, A NEW CALIBRATION IS REQUIRED.

TRIAL #	1 LOW	2 LOW	3 LOW	4 MED	5 MED	6 MED	7 HIGH	8 HIGH	9 HIGH
REFERENCE POINT									
COUNTS									
GROSS WEIGHT									
TARE WEIGHT									
NET WEIGHT									

WEIGHTS SUM OF LOW REF. ________ SUM OF MEDIUM REF. ________ SUM OF HIGH REF. ________
COUNTS SUM OF LOW REF. ________ SUM OF MEDIUM REF. ________ SUM OF HIGH REF. ________

LOW REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

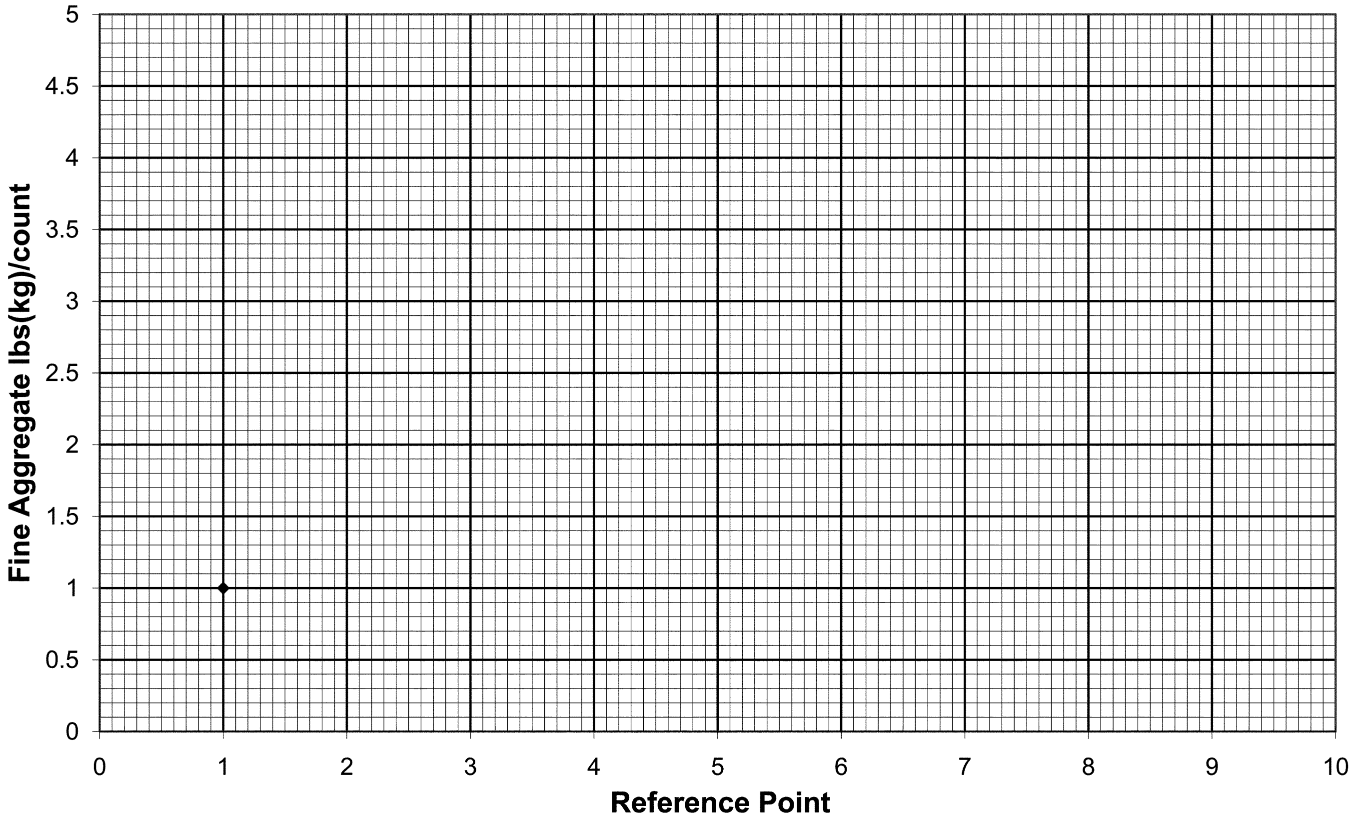
MEDIUM REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

HIGH REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

These data are to be plotted on a graph with the X axis being the reference point setting and the Y axis being lbs(kg) per count. This graph will be used in conjunction with the MIXTURE DESIGN WORKSHEET to determine the proper gate setting.

Note: The following graph is an example that could be used in the calibration of VMCM equipment. Different manufacturers may have different ranges of Reference Points. A graph with a different scale may have to be developed to fit the specific equipment.

FINE AGGREGATE GRAPH



VMCM MIXER COARSE AGGREGATE CALIBRATION WORKSHEET

The purpose of this document is to collect data so that flow graph for a particular coarse aggregate can be developed. The actual coarse aggregate to be used in concrete production must be used.

OWNER ____________________
UNIT SERIAL # ____________________

SOURCE OF COARSE AGGREGATE ____________________
TYPE OF FINE AGGREGATE ____________________ DATE __________

1. DISCONNECT CEMENT FEEDING MECHANISM.
2. ENSURE ANY AGGREGATE RETENTION ITEMS ARE ADJUSTED PROPERLY.
3. FOR TWO AGGREGATE BIN SYSTEMS, FILL ONLY ONE BIN APPROXIMATELY HALF FULL.
4. ENSURE THE REFERENCE INDICATOR IS PROPERLY ADJUSTED AND CALIBRATED.
5. AFTER A CHANGE IS MADE TO THE METERING DEVICE SETTING, ENSURE ALL RETAINED MATERIAL FROM THE ORIGINAL SETTING IS DISCHARGED.
6. A CALIBRATION IS REQUIRED FOR EACH MATERIAL. IF YOU CHANGE MATERIALS EITHER BY SOURCE OR GRADUATION, A NEW CALIBRATION IS REQUIRED.

TRIAL #	1 LOW	2 LOW	3 LOW	4 MED	5 MED	6 MED	7 HIGH	8 HIGH	9 HIGH
REFERENCE POINT									
COUNTS									
GROSS WEIGHT									
TARE WEIGHT									
NET WEIGHT									

WEIGHTS	SUM OF LOW REF.		SUM OF MEDIUM REF.		SUM OF HIGH REF.	
COUNTS	SUM OF LOW REF.		SUM OF MEDIUM REF.		SUM OF HIGH REF.	

LOW REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

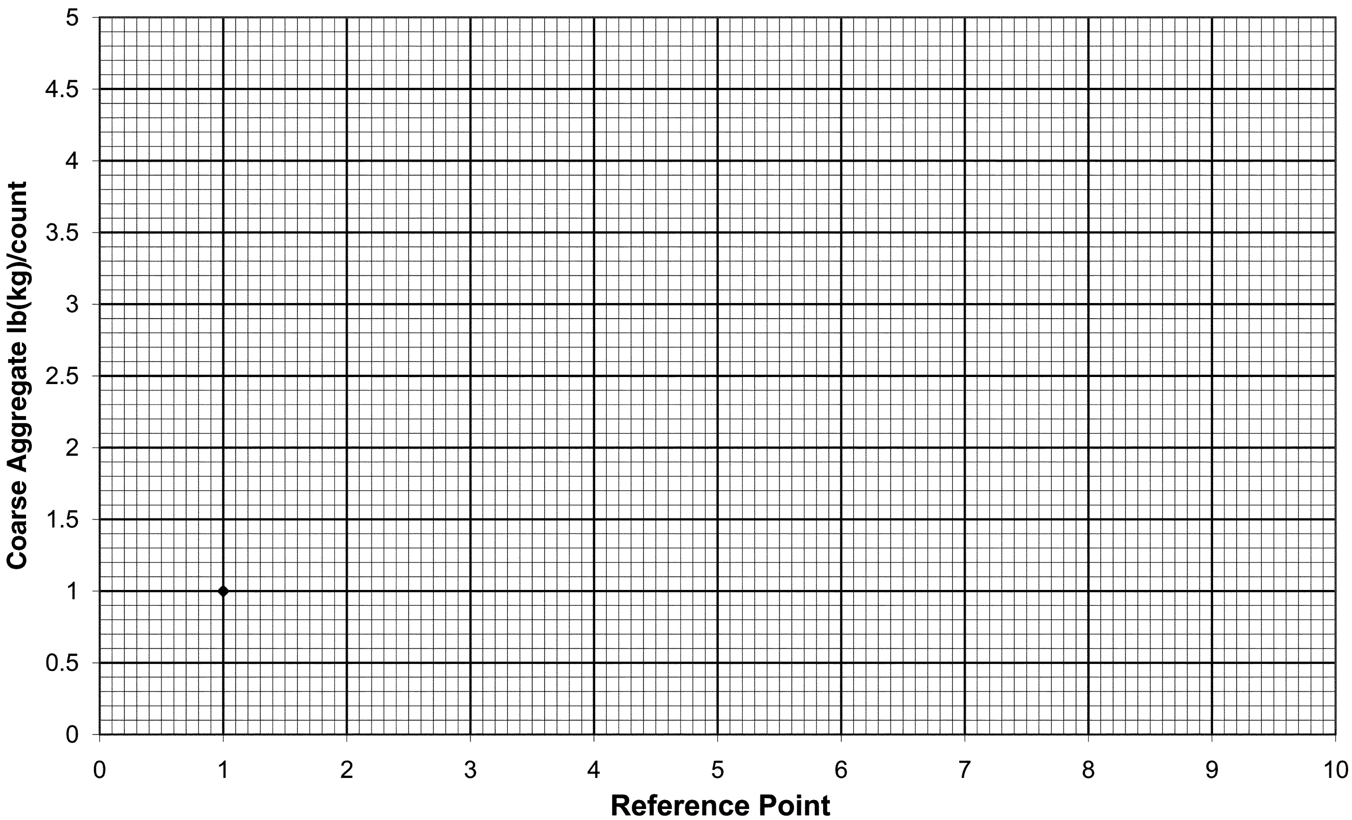
MEDIUM REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

HIGH REFERENCE POINT
TOTAL POUNDS (KG) ________/ BY TOTAL COUNT __________ = ________ LBS(KG)/COUNT

These data are to be plotted on a graph with the X axis being the reference point setting and the Y axis being lbs(kg) per count. This graph will be used in conjunction with the MIXTURE DESIGN WORKSHEET to determine the proper gate setting.

Note: The following graph is an example that could be used in the calibration of VMCM equipment. Different manufacturers may have different ranges of Reference Points. A graph with a different scale may have to be developed to fit the specific equipment.

COARSE AGGREGATE GRAPH



VMCM ADMIXTURE CALIBRATION WORKSHEET

VMCM UNIT SERIAL # ____________ DATE: ____________

Admixture name: ____________

Source: ____________ MASS OR VOLUME UNITS USED: ________

Recommended dosage rate: ____________ per ________ lbs(kg) cement

CEMENT DISCHARGE TIME ______ seconds per 100 lbs(kg)
(from Cement Calibration Worksheet)

Note: Admixture systems can vary widely in type and operation. Most systems have a range in which they operate most efficiently and consistently. Refer to the manufacturer's operating instructions to determine which system should be utilized for the particular admixture. It may be necessary to dilute some very low addition rate or viscous liquid admixtures to ensure proper flow. Contact the admixture supplier and/or the admixture system manufacturer to confirm if this is acceptable.

CALIBRATION

	LOW SETTING			MEDIUM SETTING			HIGH SETTING		
REFERENCE POINT									
TIME									
MASS OR VOLUME									
MASS OR VOLUME PER MINUTE									

LOW SETTING AVERAGE [ ] MED SETTING AVERAGE [ ] HIGH SETTING AVERAGE [ ]

Plot the above data on the ADMIXTURE GRAPH worksheet.

Determine the number of 100 lbs(kg) increments discharged per minute.

60 Seconds/min divided by ______ seconds/100 lbs(kg) discharge time = ______ 100 lbs(kg) increments/min

______ 100 lbs(kg) increments/min times ______ dosage rate units/100 lbs(kg) increment = ______ units/min rate.

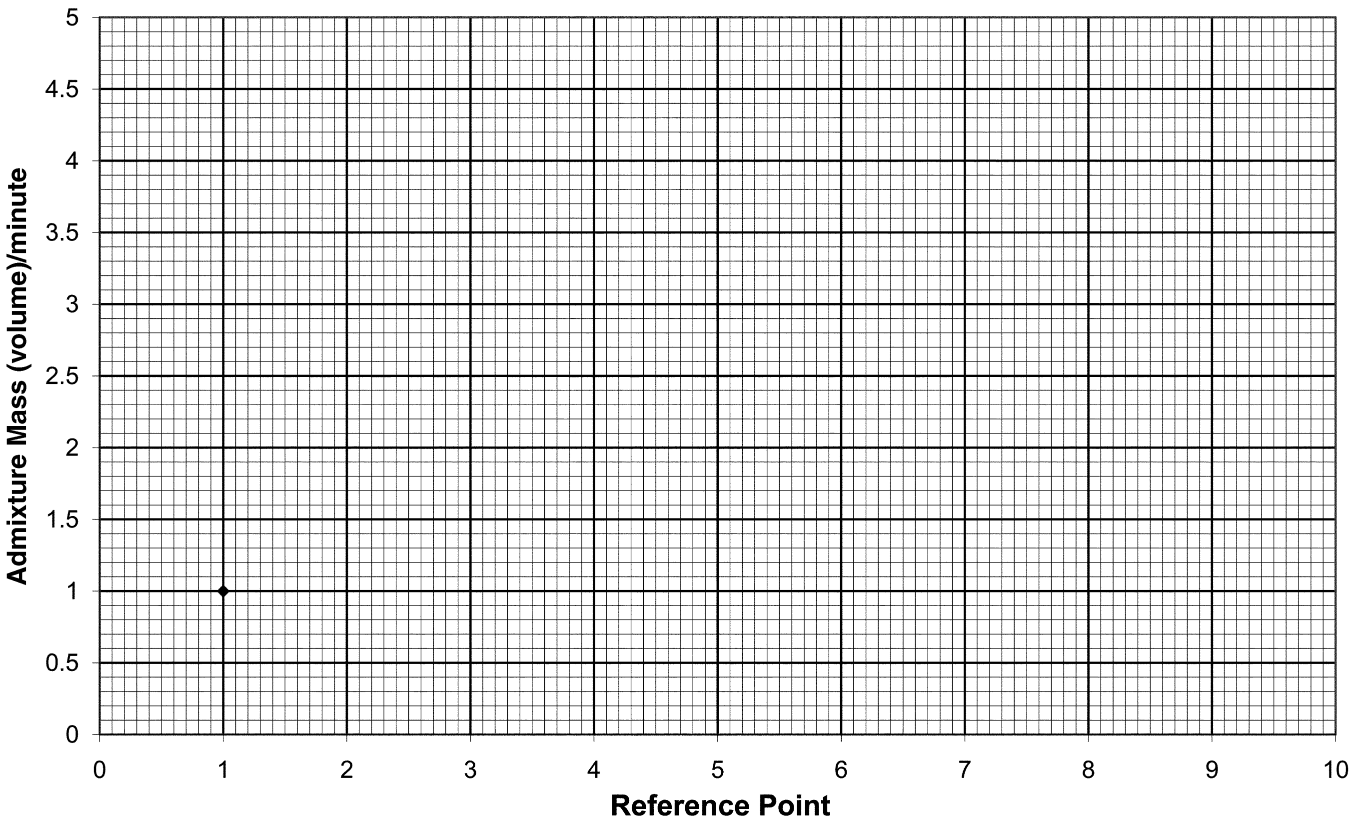
From the ADMIXTURE GRAPH, locate the units/min on the Y axis, move horizontally to the right to the data line, and then move vertically down to determine the proper admixture reference setting.

ADMIXTURE REFERENCE POINT SETTING ________

If the recommended admixture dosage is a range of values, the above step can be repeated to arrive at a range of reference point settings. It is recommended that the setting is checked by timing and collecting a sample of the admixture discharge. The timing should be at a minimum the time required to discharge 100 lbs(50 kg) of cement.

Note: The following graph is an example that could be used in the calibration of VMCM equipment. Different manufacturers may have different ranges of reference points. A graph with a different scale may have to be developed to fit the specific equipment.

ADMIXTURE GRAPH



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American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

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Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment

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