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PRODUCT BULLETIN

Sizing and Selecting
Armstrong *VMSPak* Pressure Booster Systems

Sizing and Selecting a VMSPak Pressure Booster System

1. Essential Information

The essential information required for sizing a booster system is:

- System demand flow rate (in USgpm or L/s).
- System pressure requirement at the discharge flange of the booster. This is the pressure that the booster has to overcome to be able to provide water at the top of the building (in psi or kPa).

If these are unknown they must be calculated.

2. The Demand Flow Rate.

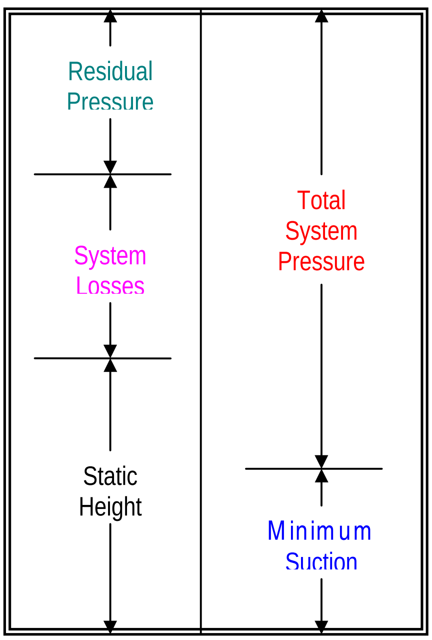
Each appliance that uses water within the building is deemed to have a loading unit. These are detailed in Appendix A for British and North American Standards.

The total number of demand units can be determined by multiplying the number of appliances/fixtures by the demand/fixture loading units. The total fixture unit load is the sum of this calculation. The total fixture unit load is then converted using the demand unit conversion graph (also in Appendix A) to produce the required flow rate (design demand) for the building.

3. The System Pressure

The system pressure is calculated by the following equation.

$$\text{static height} + \text{system losses} + \text{residual pressure} - \text{suction pressure} = \text{total system pressure}$$



Static Height - the difference between the suction water level and the highest discharge point in the building. This is generally obtained from site drawings or measurements.

System Losses – the aggregate of losses due to pipes, valves & fittings and friction at maximum demand. It is recommended that 5 psi (35 kPa) of pressure loss be assumed within the booster package itself and factored into the pump head calculations.

Residual Pressure – the pressure that is required by the fitting at the highest point. A minimum of 30 psi (207 kPa) should be used to operate flush valves.

Minimum Suction Pressure – the minimum pressure at the building side of the water meter after the back-flow prevention device. Where a supply tank is being used, this is the minimum static water level in the tank above the booster system.

4. Pumping Arrangement

Once the system pressure and the demand flow rate have been calculated, it is necessary to select the pump arrangement to suit the requirements of the building. Booster systems can be supplied in a variety of configurations.

2 pumps – duty/standby or lead/lag (100/100% or 50/50%)
3 pumps – duty/assist/standby or lead/lag/lag (50/50/50% or 33/33/33%)
4 pumps – duty/assist/assist/standby or lead/lag/lag/lag (33/33/33/33% or 25/25/25/25%)

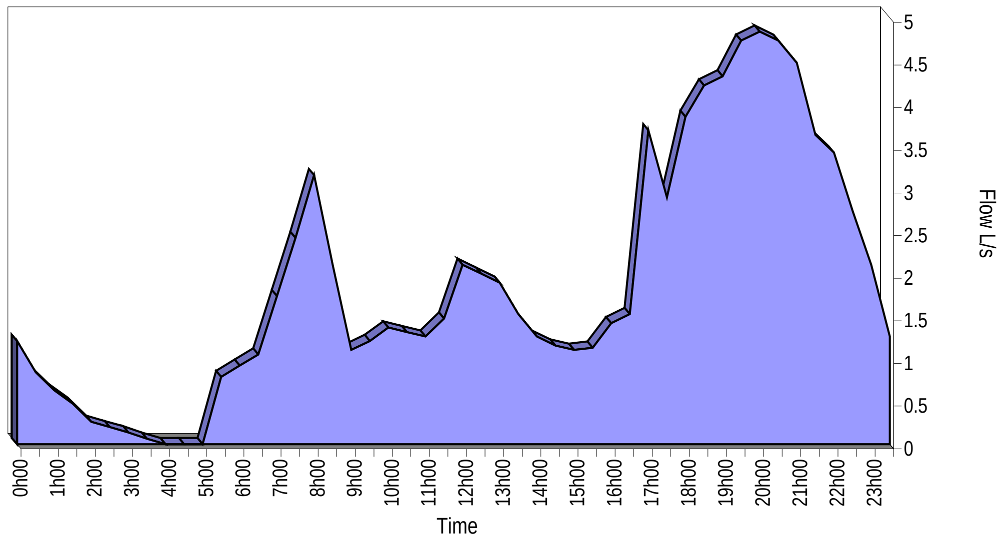
The designer can determine the number of pumps based on the building load profile. There are a few considerations to be taken into account. (Also see shut off Head – Item 9). A relatively low flow rate can be met with a two pump system running duty/standby (therefore having full capacity should one of the pumps fail) or on a lead/lag basis (total booster pump flow equals building demand). For larger demand flow rates a two-pump system could be used, but would involve the selection of larger pumps.

The demand load profile can vary drastically by application. Commercial and multi-occupancy residential buildings typically require peak flows only at brief periods during the day. Where peak demands fluctuate greatly, it is more operationally efficient to use three or four smaller pumps. The application of several smaller pumps reduces the power consumption and load on the mains water supply and reduces changes of velocity flow in the connecting pipe work. This can reduce the likelihood of water hammer and other related operating noise.

5. Selecting the Pumps

To select pumps, ACE or the quick reference chart in appendix B should be used. Remember to factor the required duty (i.e. duty/standby or lead/lag) when determining the system design flow rate. Select pumps that will comfortably meet the duty requirement, and will not over-pressurise the system at low flow rates. The quick reference chart indicates single pump performance.

6. System Demand



The above chart illustrates a typical demand curve through the course of a day with peak times in the morning and early evening.

For smaller systems (less than 100 USgpm / 6 L/s), the peak demand is typically 75% of the design demand therefore an 80% duty pump with an 80% standby pump would allow smaller pumps to be selected with confidence that the peak demand would be satisfied. The booster design flow for this curve would be about 80 USgpm (5 L/s).

For larger systems (200 USgpm / 12.6 L/s or greater), a 20%/40%/40% flow split could be used to reduce energy consumption during the evening hours (from 11pm to 6am).

The demand curve will vary depending on the application. For a hotel, the load variation will be lower with the peak loads in the morning and early evening. For an office, the load will vary greatly with the peak loads occurring from 10am to 3pm. Provided the booster does not supply cooling tower makeup water, long periods of no demand can be anticipated from 7pm through the night.

7. WRc Regulations (Great Britain)

The Water Regulations Advisory Scheme (formerly The Water Regulations Council - WRc) states that any fitting that is to be used for domestic water within commercial buildings it must comply with the following bylaws:

Bylaw 7 (1)
No material or substance which causes, or is likely to cause, contamination of water shall be used in the construction or installation of any pipe or water fitting which conveys or receives water supplied for domestic purposes.

Bylaw 51
No water fitting which conveys water supplied by the undertakers for domestic purposes shall - (a) be made wholly or partially of, or incorporate, or (b) be lined or coated with, any material or substance which contaminates, or is likely to contaminate, such water by altering its colour, odour, taste or composition.

All the pumps and fittings used in the booster systems have approval from WRc.
The header materials that are currently offered are:

- Copper (Standard for small bore pipework)
- Galvanised Steel (used in large bore pipework applications/not available in North America)
- Stainless Steel (at customers request. Used for de-mineralised water)
- Plastic (at customers request. Used for de-mineralised water/not available in North America)

8. North American Plumbing Standards

Plumbing Codes in most cities do not allow galvanised steel piping to be used in a domestic water system. As such, systems manufactured for North American installations are completely free from galvanised steel. All wetted components are stainless steel, cast iron, copper, or bronze.

9. Pump Shut-off Head

When designing a system with multistage pumps, it is important to consider the "steepness" of the pump curve. The shut off head (SOH) is defined as the amount of pressure that will be generated by a booster pump when it is running at closed valve (i.e. when there is no demand for water). This can be found on the pump curve as the pressure that the pump will generate at no flow. The shut off head for each pump is tabulated on the selection tables as the curves are truncated. Truncation of the curves is to ensure that there is enough pressure range across the curve to ensure the controls will operate effectively.

The shutoff head may be substantially higher than the system pressure, so care must be taken to advise the customer of the shut of head to ensure that any pipe work or fittings in the system can withstand this pressure. Should the shutoff head be too high for the system to withstand, there are a number of ways to select booster pumps to eliminate this concern. Shutoff head can be decreased by selecting a larger size pump for the same duty flow requirement, or by increasing the number of pumps within a booster system. More effectively, application of Variable Frequency Drives (VFD) on the booster system can eliminate this problem entirely.

For pressure sequencing systems, it is important to have enough pressure variation across the pump curve to properly sequence the pumps and prevent short cycling. Pump selections should be made such that the pump design flow is in the "flat of the curve". The flat of the curve is indicated in Appendix B, but can also be calculated using the following equations. This is known as the effect of the controls margin on the curve. All Pressures are in kPa (1 psi ~ 7 kPa).

$$\text{The Flat of the Curve} = \text{Pump SOH - Margin - Pressure Switch Differential}$$

$$\text{Margin} = \text{Pump SOH x } 0.046 \quad \text{min } 20\text{kPa} \quad \text{max } 50\text{kPa}$$

$$\text{Pressure Switch Differential} = \text{Pump SOH x } 0.115 \quad \text{min } 60\text{kPa} \quad \text{max } 120\text{kPa}$$

10. Jockey Pumps

A jockey pump is a pump that is smaller than the main pumps in the booster system. Jockey pumps are applied to operate at low demands conserving energy (because of the smaller motor size), will provide less stress to the pipe work within the building, due to the lower flow rate and can reduce excess cycling within the system.

As a standard guide a jockey is sized to 10 to 20% of the duty flow rate with the main pumps sized as indicated above. The main pumps should be sized to provide the remainder of the duty flow required (i.e. 20/40/40 or 10/45/45 split). The jockey should be sized on the same pressure requirement as the rest of the pumps. Care is to be taken when selecting the jockey pump, as the shut off head of the jockey must not be lower than the shut off head of the main pumps. Ideally the jockey pump shutoff head should be 7 psi (50 kPa) above that of the main pumps. This is to ensure that the pressure sequencing works properly – the jockey pump being the first on and the last off. In design, this also ensures that the overall booster system shut off head will be the same as the jockey pump shut off head.

11. Booster System Controls

There are three different types of controls for the booster systems:

- Pressure Switch controlled – Mechanical control of pumps
- Microprocessor controlled – Electronic control of pumps with digital display
- Variable Speed controlled – VFD (sometimes referred to as Inverters) with electronic controller

Variable speed drives should be sized for maximum flow rate at full speed. As the demand falls in the system, the speed decreases to maintain a constant pressure. This operating mode reduces energy costs and removes pressure fluctuations in the system. If the pressure transducer is mounted remotely at the top of the system then the lowest possible speed will be achieved.

Microprocessor/variable speed control panels use a software package to enable the booster system to interface with other controllers and Building Management Systems. This allows alarms and settings to be monitored from a remote central location.

Current control is not recommended on multistage pumps due to their characteristic flat BHP curve.

12. Flexible Connections and Anti-Vibration mounts

Flexible connections should be selected in relation to the header sizes of the booster system. This can be found from the General Arrangement drawings.

Anti-Vibration mats or pads must be used to isolate the building from vibration. Anti-vibration pads should be cut 2.5 x 2.5 x 0.75" (60 x 60 x 18 mm) square and inserted under the corners of the booster system. For larger systems, it is recommended to use 2 or more pads under anchoring points.

13. Suction Storage Tank Capacities

Unless otherwise specified booster systems are designed to operate on a positive supply pressure (flooded suction) from a storage tank or main. If a suction storage tank is used, it should be situated close to the system and at the same level. The suction pressure is negligible in the overall design pressure calculation. However, should the tank be situated in a higher location than the booster system (i.e. on the rooftop with the booster in the basement) then the suction pressure will become an important factor in the equation.

Should a storage tank be required to be supplied with the booster system, consult the table below for recommended minimum storage capacities for hot and cold water. This information has been adapted from BS6700.

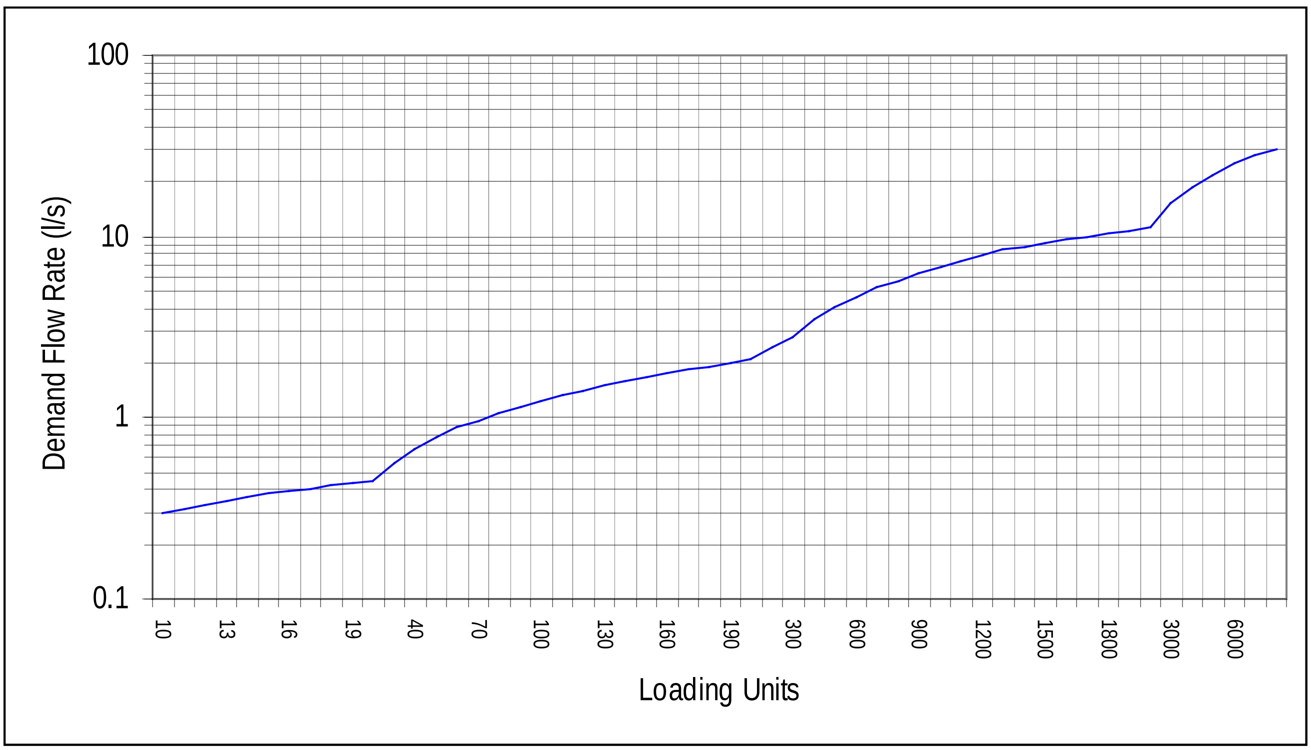
TYPE OF BUILDING	MINIMUM STORAGE (LITRES)
Hostel	90 per bed
Hotel	200 per bed
Offices – with Canteen – without Canteen	45 per employee 40 per employee
Restaurant	7 per meal
Day School – Nursery – Primary – Secondary – Technical	15 per pupil 15 per pupil 20 per pupil 20 per pupil
Boarding School	90 per pupil
Childrens Home/Residential Nursery	135 per bed
Nurses' Home	120 per bed
Nursing or convalescent home	135 per bed

Appendix A – Flow Calculations

British Standard Sizing Information
Demand Units

APPLIANCE	LOADING UNITS
WC	2
Wash Basin	1.5
Bath Tap	10
Shower	3
Sink Tap	3
Washing Machines	3
Dishwashers	3

Demand Unit To Flow Rate Conversion Graph
Graph and Demand units adapted from BS6700 nomogram



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North American (ASPE) Standard Sizing Information
Extract taken from the National Standard Plumbing Code

TYPE OF FIXTURES	WATER SUPPLY FIXTURE UNITS - WSFU			
	Individual Dwelling Units	Serving three of more Dwelling Units	Other than Dwelling Units	Heavy Use Assembly
Bathroom Group, 1.6 GPF Gravity Tank WC	5.0	3.5		
Bathroom Group, 1.6 GPF Pressure Tank WC	5.0	3.5		
Bathroom Group, 3.5 GPF Gravity Tank WC	6.0	5.0		
Bathroom Group, 1.6 GPF Flushometer Valve	6.0	4.0		
Bathroom Group, 3.5 GPF Flushometer Valve	8.0	6.0		
Kitchen Group, Sink & Dishwasher	2.0	1.5		
Laundry Group, Sink & Clothes Washer	5.0	3.0		
INDIVIDUAL FIXTURES				
Bathtub, or combination Bath/Shower	4.0	3.5		
Bidet	1.0	0.5		
Clothes Washer, domestic	4.0	2.5	4.0	
Dishwasher, domestic	1.5	1.0	1.5	
Drinking Fountain or Watercooler			0.5	0.75
Hose Bibb (1/2" supply pipe)	2.5	2.5	2.5	
Hose Bibb, each additional (1/2" supply pipe)	1.0	1.0	1.0	
Kitchen Sink, domestic	1.5	1.0	1.5	
Laundry Sink	2.0	1.0	2.0	
Lavatory	1.0	0.5	1.0	1.0
Service Sink, or Mop Basin			3.0	
Shower	2.0	2.0	2.0	
Shower, continuous use			5.0	
Urinal, 1.0 GPF			4.0	5.0
Urinal, greater than 1.0 GPF			5.0	6.0
WC, 1.6 GPF Gravity Tank	2.5	2.5	2.5	4.0
WC, 1.6 GPF Pressure Tank	2.5	2.5	2.5	3.5
WC, 1.6 GPF Flushometer Valve	5.0	5.0	5.0	8.0
WC, 3.5 GPF Gravity Tank	3.0	3.0	5.5	7.0
WC, 3.5 GPF Pressure Tank	7.0	7.0	8.0	10.0
Whirlpool Bath or Combination Bath/Shower	4.0	4.0		

WATER DEMAND TABLE		
FIXTURE UNITS	FLUSH TANKS DEMAND (USgpm / lps)	FLUSH VALVES DEMAND (USgpm / lps)
100	44 / 2.8	68 / 4.3
200	65 / 4.1	91 / 5.8
300	85 / 5.4	110 / 7.0
400	105 / 6.7	125 / 7.9
500	125 / 7.9	140 / 8.9
750	170 / 10.8	175 / 11.1
1000	210 / 13.3	218 / 13.8
1250	240 / 15.2	240 / 15.2
1500	270 / 17.1	270 / 17.1
1750	300 / 18.9	300 / 18.9
2000	325 / 20.5	325 / 20.5
2500	380 / 24.0	380 / 24.0
3000	435 / 27.5	435 / 27.5
4000	525 / 33.1	525 / 33.1
5000	600 / 37.8	600 / 37.8
6000	650 / 41.0	650 / 41.0
7000	700 / 44.1	700 / 44.1
8000	730 / 46.0	730 / 46.0
9000	760 / 47.9	760 / 47.9
10000	790 / 49.8	790 / 49.8

Notes:

1. A Bathroom Group for the purposes of this table consists of not more than one WC, up to two lavatories, and either one bathtub or one shower.

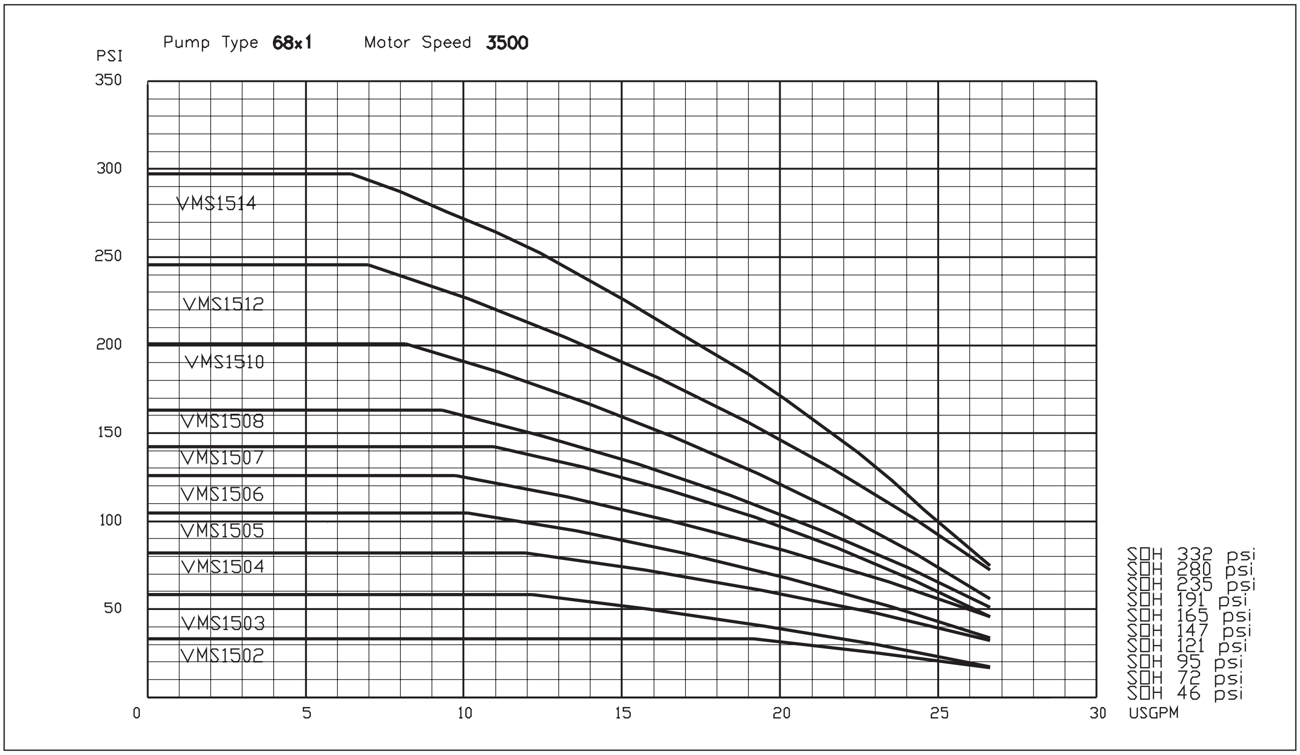
2. "Other than Dwelling Units" applies to business, commercial, industrial and assembly occupancies other than those defined under "Heavy use Assembly". Included are the public areas in hotels, motels and multi-dwelling buildings.

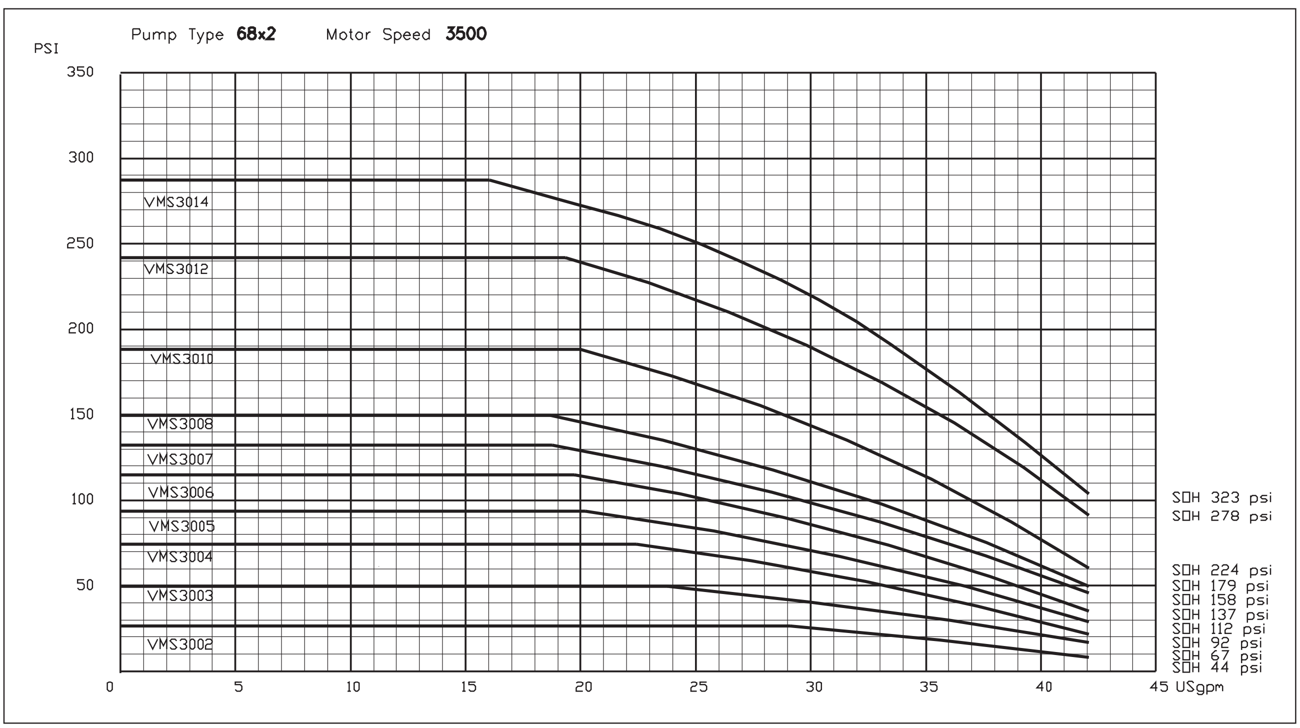
3. "Heavy use Assembly" applies to toilet facilities in occupancies which have heavy but intermittent, time based demands on the water supply system, such as; schools, stadiums, racecourses transportation terminals, theatres and similar occupancies.

4. For fixtures or supply conditions likely to impose a continuous flow demand, determine the required flow in gallons per minute (GPM) and add it separately to the demand (GPM) for the distribution system or portion thereof.

Appendix B – Range Charts

60 Hz





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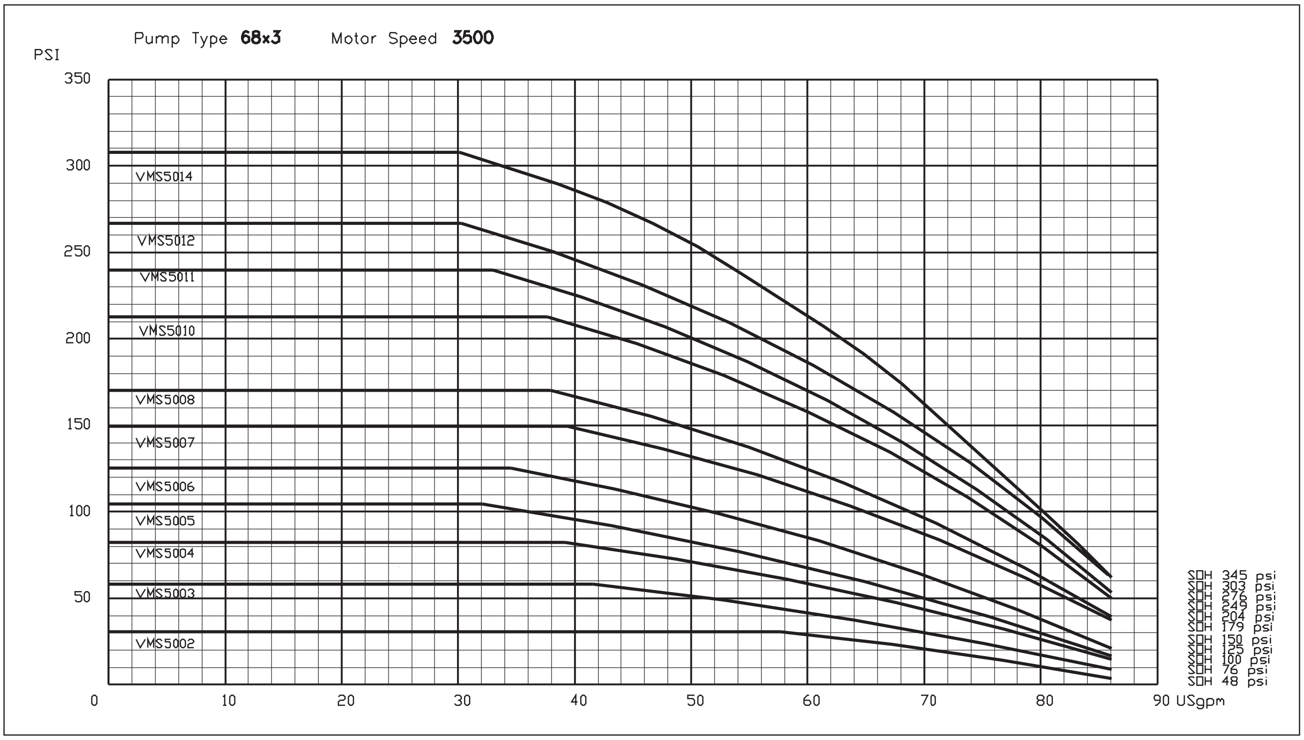
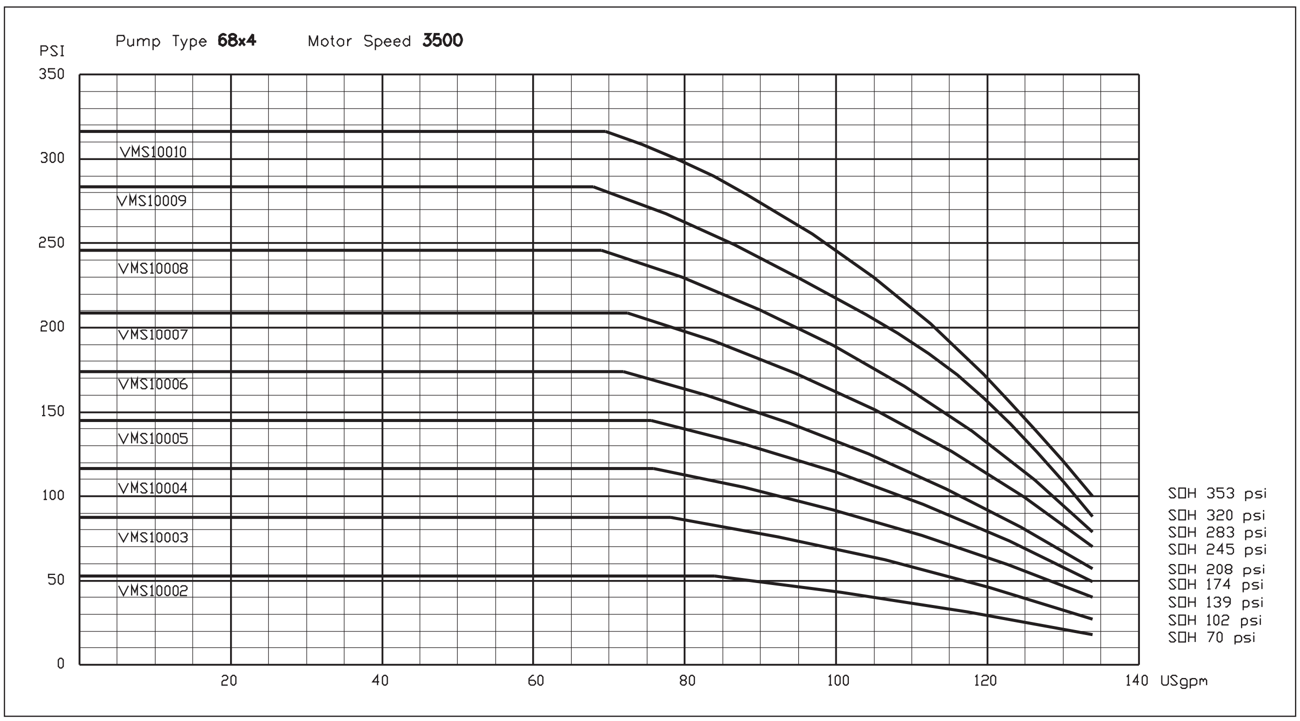
60 Hz





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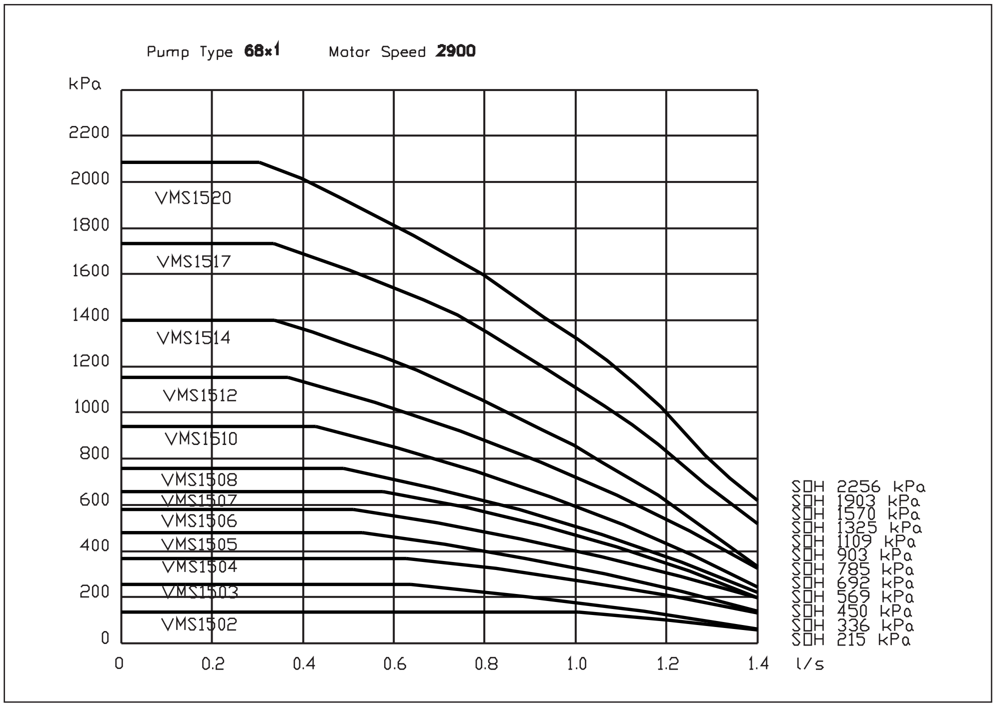
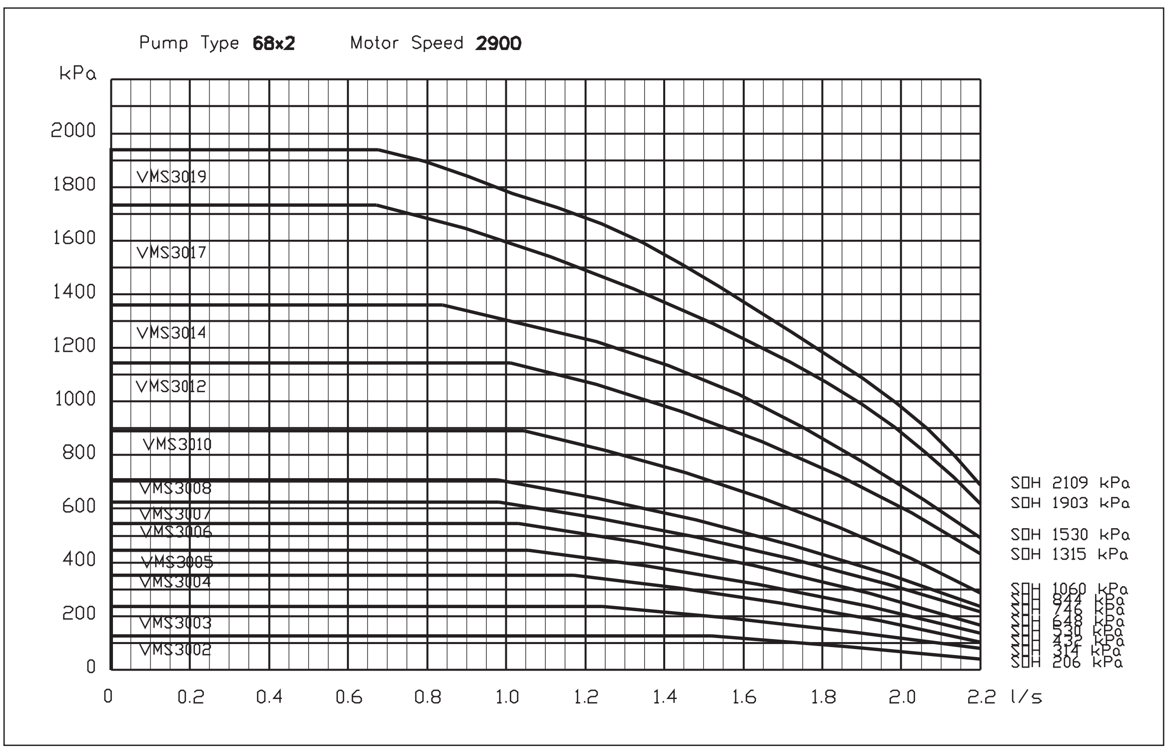
50 Hz





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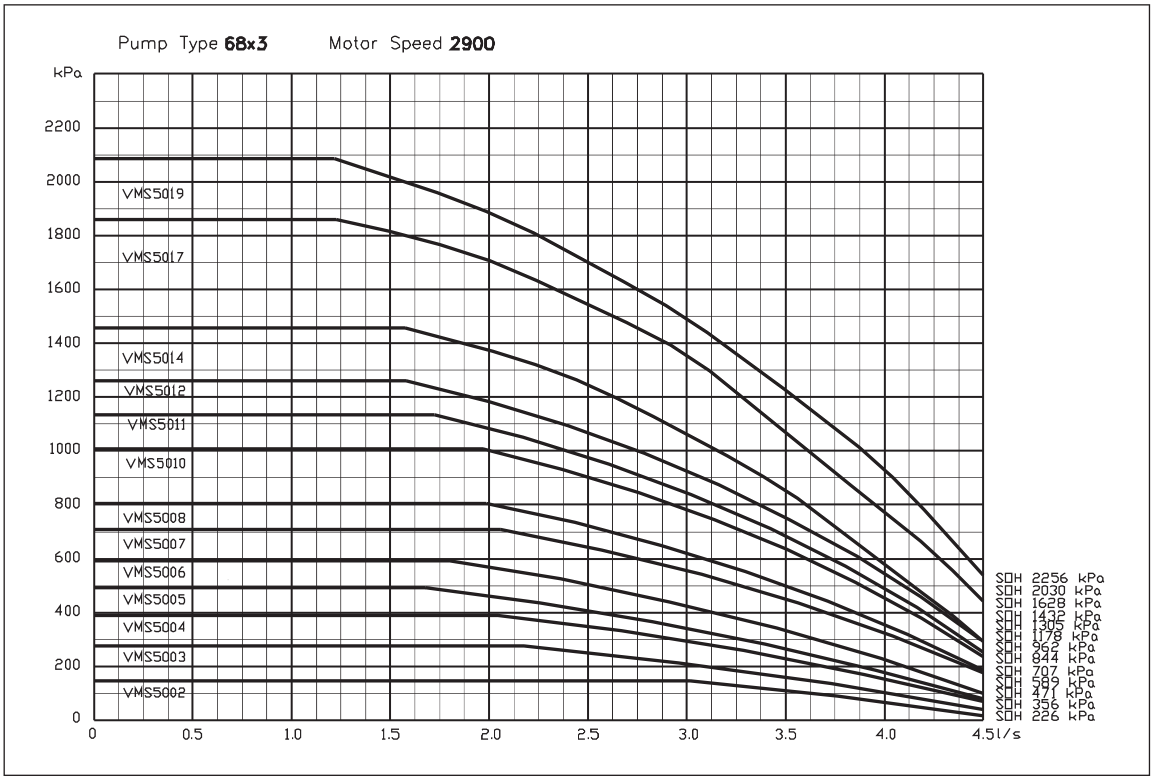
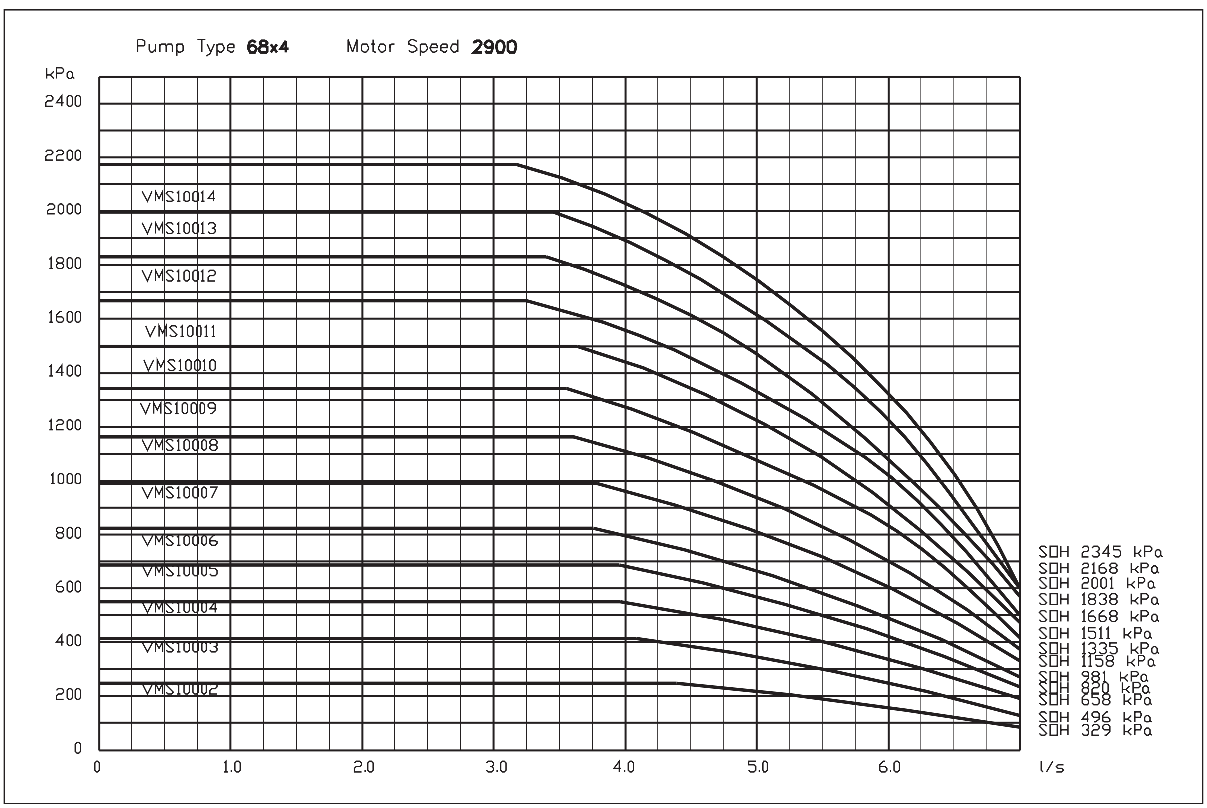
50 Hz





Appendix C – Examples

Example 1: 50 Hz British Standard

15 storey building with 30 dwelling units. The height of each storey is 2.8m with losses at 0.05m/m of static head. Pressure to be achieved at the top of the system is 1 bar.

Static head = 15 x 2.8 = 42 m
Losses = 0.05 x 42 = 2.1 m
Residual = 1 bar = 10 m
Total system pressure = 54.1m = 5.3 bar = 530 kPa

In each flat there is:

Bath	Loading Unit - 10
Basin	Loading Unit – 1.5
Wc	Loading Unit - 2
Sink	Loading Unit – 3
Washing Machine	Loading Unit – 3
Total	Loading Unit – 19.5
Total for block	30x19.5 = 585 units

From Appendix A, the overall flow rate for the building will be 4.4 L/s

If a standard 3 pump system of lead/lag/lag is chosen, then each pump should be sized for 1.46 L/s at 530 kPa

From the curves in Appendix A, possible options are a booster system with three VMS3008 (SOH 844 kPa) OR three VMS5006 (SOH 707 kPa)

The kW rating of the motors are 1.85kW for the VMS3008 and 2.2kW for the VMS5006. The economic costs and overall price will be less for the VMS3008.

Final selection
Main pumps – 3 off VMS3008 (1.85 kW, SOH 844 kPa) duty: 1.46 L/s @ 530 kPa each

Example 2: 60 Hz North American Standard

15 storey building with 7 dwelling units per floor. The height of each storey 10 feet with losses at 5% of static head. Pressure to be achieved at the top of the system is 30 psi. The supply pressure on the street after the water meter and back-flow preventer is 35 psi.

Static head = 15 x 10 = 150 feet / 2.31ft/psi = 65 psi
Losses = 0.05 x 65 = 7 psi + 5 psi = 12 psi (including package losses)
Residual = 30 psi
Supply = 35 psi
Total system pressure = 65 + 12 + 30 – 35 = 72 psi

Each unit has the following fixtures:
Bathroom Group w/ 1.6gpf gravity tank - 5.0 units
Dishwasher - 1.5 units
Clothes washer - 4.0 units
Kitchen Sink - 1.5 units
Total Fixture Units = 12

Total for building 15 x 7 x 12 = 1,260 units

From the flow table the total flow rate for the building will be between 240 to 270 USgpm (approximately 250 USgpm)

If a standard three pump system of lead/lag/lag is chosen, then each pump should be sized for 84 USgpm @ 72 psi

Final selection
Main Pumps - 3 off VMS10003 pumps (7.5hp, SOH 102 psi)

Example 3: 50 Hz British Standard

A duty flow of 2.2 L/s and a static head of 400 kPa is to be used and a booster system with a jockey pump is to be selected.

The jockey pump will provide 0.22 L/s (10%) at 400 kPa with the other pumps covering the remainder of the duty at 1.98 L/s @ 400 kPa

In this case a three pump booster system will be selected with jockey/duty/standby arrangement.

From the curves the original choice for the jockey pump would be a VMS1505 (0.75 kW, SOH 569 kPa) with the main pumps being either VMS3010 (2.2 kW, SOH 1060 kPa) or a VMS5005 (1.85 kW, SOH 589 kPa).

The main pump selection is biased towards the VMS5005 for a number of reasons –

a) The shut off head is very high fir the VMS3010 (10 bar).
b) The kW rating of the pump motors is higher in the VMS3010 so the overall economic running costs are going to be higher.
c) The selection is very close to the end of the curve which is not close to the best efficiency flow point of the pump.

As a result of this selection, the main pumps now have a higher shut off head than the jockey pump, therefore we need to increase the size of the jockey pump to ensure the control system will function properly. The jockey selection is revised as VMS1506 (1.1 kW, SOH 692 kPa).

Final Selection
Jockey pump – VMS1506 (1.1 kW, SOH 692 kPa) duty: 0.2 L/s @ 400 kPa
Main pumps – 2 off VMS5005 (1.85 kW, SOH 589 kPa) duty: 1.98 L/s @ 400 kPa each