Pre-commission Cleaning of Pipework Systems (2nd edition)

Including advice on fit-out works

By Chris Parsloe
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The technical information and procedures in this Guide were developed with input from project steering groups drawn from industry representatives and BSRIA staff.

This Application Guide is a revision to BSRIA Application Guide AG 1/2001 (see Preface). As the guidance derives from both the original and newly formed steering groups, both are acknowledged:

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The author has sought to incorporate the views of the steering/review group, but final editorial control of this document rests with BSRIA. It is not intended that contracts or specifications refer to the Guide in its entirety, rather that direct references are made to specific sections to suit the particular circumstances.
System contaminants such as millscale, jointing compound, and building debris will inevitably be found in newly-fabricated heating and cooling pipework systems. If allowed to remain in the system in sufficient quality, these contaminants will make the system prone to blockage at strainers, control valves and small bore heat exchangers. They may also initiate further corrosion and encourage the growth of micro-organisms.

The subject of pre-commission cleaning of pipework systems, to remove these contaminants, was first addressed in the 1991 BSRIA Application Guide AG8/91: Pre-Commissioning Cleaning of Water Systems. Many of the recommendations in this guide were considered unconventional at the time. However, in the intervening years, experience has shown that systems which are designed and cleaned following this guidance are far less likely to suffer operating problems.

**AG1/2001**

In 2001, the first revision to AG 8/91 was launched as BSRIA Application Guide AG1/2001: Pre-Commission Cleaning of Pipework Systems. This guide was intended as a direct replacement for AG8/91. The preceding recommendations were revised in order to take on board feedback received since 1991, but also to address the growing incidence of bacteria-related problems being reported, particularly *Pseudomonas*-related problems. For reasons not fully understood, such problems had become more common during the 1990s. AG1/2001 therefore contained more information on precautionary measures to avoid or address bacteria in systems.

**AG1/2001.1**

In 2004 this latest version of the Guide was produced. At this time it was recognised that there was a serious contamination risk when new pipework sections were connected to existing systems (such as in shell and core situations). It was decided that additional guidance was required to address these particular situations.

BSRIA AG1/2001.1 therefore contains all of the recommendations provided in AG1/2001, but also has a complete new standalone section which deals with the issues raised when connecting new pipework to existing pipework.

*Chris Parsloe*

*2004*
## CONTENTS

1  **DESIGN CONSIDERATIONS** ............................................................................................................. 1

   1.1  Introduction .................................................................................................................................... 1

       1.1.1  General ....................................................................................................................................... 1

       1.1.2  Responsibilities ......................................................................................................................... 1

       1.1.3  When to chemically clean ......................................................................................................... 2

       1.1.4  Specifying for system cleaning .................................................................................................. 2

   1.2  System chemistry .............................................................................................................................. 4

       1.2.1  System contaminants .................................................................................................................. 4

       1.2.2  Choice of chemicals .................................................................................................................. 5

       1.2.3  Typical stages of a clean .............................................................................................................. 6

   1.3  Pipework system design ................................................................................................................... 6

       1.3.1  General provisions ...................................................................................................................... 7

       1.3.2  Large bore pipework ................................................................................................................ 11

       1.3.3  Plastic pipework ......................................................................................................................... 12

       1.3.4  System facilities .......................................................................................................................... 12

       1.3.5  System schematic ....................................................................................................................... 14

   1.4  Inspection and witnessing .................................................................................................................. 23

2  **INSTALLATION CONSIDERATIONS** ............................................................................................... 26

   2.1  Management .................................................................................................................................... 26

       2.1.1  General ....................................................................................................................................... 26

       2.1.2  Organisation and planning ......................................................................................................... 26

       2.1.3  Choice of chemicals .................................................................................................................. 27

       2.1.4  COSHH regulations ................................................................................................................. 28

   2.2  Pipework installation ......................................................................................................................... 29

       2.2.1  Materials storage ....................................................................................................................... 29

       2.2.2  Good installation practice ......................................................................................................... 29

   2.3  Preparation for flushing and cleaning ............................................................................................. 30

       2.3.1  Installation checks ....................................................................................................................... 30

       2.3.2  Drainage ..................................................................................................................................... 30

       2.3.3  Mains water ............................................................................................................................... 30

   2.4  Procedure for filling, pressure testing and static flushing ............................................................... 31

       2.4.1  System filling ............................................................................................................................... 31

       2.4.2  System pressure testing .............................................................................................................. 31

       2.4.3  Basic procedure .......................................................................................................................... 32

3  **SYSTEM DYNAMIC FLUSHING** ...................................................................................................... 33

   3.1  Flushing objectives ............................................................................................................................ 33

       3.1.1  Importance of water velocity ...................................................................................................... 33

   3.2  Dynamic flushing procedure ............................................................................................................ 34

       3.2.1  General considerations ................................................................................................................. 34

       3.2.2  Basic stages of a flush ................................................................................................................ 34

       3.2.3  Dynamic flushing of primary ring-main circuit ......................................................................... 36

       3.2.4  Dynamic flushing of secondary mains pipework ..................................................................... 37

       3.2.5  Dynamic flushing of horizontal mains to each floor ................................................................. 40

       3.2.6  Final full system flush ............................................................................................................... 44

       3.2.7  Reinstatement of terminal units and main plant items .............................................................. 46
4 CHEMICAL CLEANING PROCEDURE .................................................................47
  4.1 Introduction ...............................................................................................47
    4.1.1 Importance of pre-flushing .................................................................47
    4.1.2 The importance of flow .......................................................................47
    4.1.3 The importance of temperature .........................................................48
    4.1.4 Duration of chemical circulation within the system .........................48
    4.1.5 Disposal of chemicals .......................................................................48
  4.2 Cleaning options .......................................................................................49
    4.2.1 Degreasing ..........................................................................................49
    4.2.2 Biocide wash .......................................................................................49
    4.2.3 Removal of surface oxides .................................................................50
    4.2.4 Effluent disposal/final flushing ............................................................52
    4.2.5 Neutralisation ......................................................................................52
    4.2.6 Passivation ..........................................................................................52
    4.2.7 Corrosion inhibitor/biocide dosing .....................................................52
    4.2.8 Treatment up to system handover .......................................................53
  4.3 On-going water treatment .................................................................54

5 CONNECTIONS BETWEEN NEW AND EXISTING SYSTEMS .........................55
  5.1 Scope of clean required ............................................................................55
  5.2 Water sampling .......................................................................................55
  5.3 Shell and core type projects ....................................................................56
    5.3.1 Provision for future extension ............................................................56
    5.3.2 Temporary pump sets .........................................................................57
    5.3.3 The cleaning process ..........................................................................59
    5.3.4 Maintaining system cleanliness ..........................................................59
    5.3.5 Final connection ................................................................................60

APPENDICES

APPENDIX A - Calculation of mean flushing velocities ..............................62
APPENDIX B - Procedure for pre-commission cleaning with inhibited acid ........63
APPENDIX C - Polymer cleaning (with side stream filtration/separation) ........64
APPENDIX D - Procedure for pre-commission cleaning with formulated products ....66
APPENDIX E - Example certificate of conformity for system cleanliness ..........67
TABLES

Table 1: Example of design information required to flush and chemical clean the system................. 3
Table 2: Chemical categories.............................................................................................................. 6
Table 3: Recommended incoming water main sizes ........................................................................... 7
Table 4: Interpretation of results from bacterial analysis in closed circuit systems.......................... 25
Table 5: Minimum water velocities required to move 5 mm diameter steel particles in horizontal medium grade steel pipework .................................................. 33

FIGURES

Figure 1: Minimising trapped air during system fill ........................................................................ 9
Figure 2: Side stream filtration unit ............................................................................................... 13
Figure 3: Hydrocyclone unit ......................................................................................................... 14
Figure 4: Typical system schematic .................................................................................................. 15
Figure 5: Detail A – Provisions at heat exchangers ......................................................................... 16
Figure 6: Detail B – Provisions at primary pump ........................................................................... 17
Figure 7: Detail C – Temporary flushing tank provisions ................................................................. 18
Figure 8: Detail D – Provisions at secondary pumps ........................................................................ 19
Figure 9: Detail E – Provisions at horizontal mains ....................................................................... 20
Figure 10: Detail F – Provisions at heater/cooler batteries .............................................................. 21
Figure 11: Detail G – Provisions at risers ...................................................................................... 22
Figure 12: Valve reference numbers .............................................................................................. 35
Figure 13: Flush to drain with strainer isolated .............................................................................. 36
Figure 14: Flush to drain with primary ring-main operational ......................................................... 37
Figure 15: First flush through horizontal mains ............................................................................. 39
Figure 16: Staged flush of terminal unit bypasses ......................................................................... 41
Figure 17: Forward flush through horizontal mains on top floor ................................................... 42
Figure 18: Forward flush through horizontal mains on intermediate floors .................................... 43
Figure 19: Final flush through entire system .................................................................................. 45
Figure 20: Two-stage flush through terminal unit ......................................................................... 46
Figure 21: Branch connection showing provisions for future connection .................................... 56
Figure 22: Temporary pump arrangement ..................................................................................... 58
**LIST OF SYMBOLS**

- Isolating valve
- Double regulating valve
- Orifice plate
- Test point
- Strainer
- Motorised four-port valve
- Motorised three-port valve
- Drain-off cock with hose connection
- Pressure gauge
- Temperature gauge
- Non-return valve
- Pump
- Fan coil unit
- Radiator (with isolating and lockshield valves)
- Gas fired boiler
- Water meter
- Automatic air vent
- Manual air vent
- Flexible coupling
- Flexible hose
I DESIGN CONSIDERATIONS

1.1 INTRODUCTION

1.1.1 General

The designer should address the requirements for system cleaning at an early stage in the design of the system. The designer should aim to assess:

- Which methods of cleaning are most appropriate for the system
- Whether chemical cleaning is important to the successful operation of the system
- What design features need to be incorporated to facilitate the cleaning process.

In consideration of these aspects, the designer should advise if a cleaning specialist is required and one should be appointed. In most cases, the designer will benefit from the involvement of a cleaning specialist at the design stage of the project. The appointed cleaning specialist should be a suitably qualified person with a proven track record in system flushing and chemical cleaning.

1.1.2 Responsibilities

As early as possible the designer should aim to clarify the roles of the installing contractor and cleaning specialist during the cleaning process. Some installing contractors undertake system flushing themselves, and employ a cleaning specialist for the chemical clean only. Others prefer to sub-contract the entire cleaning process. Both arrangements are acceptable, although to ensure the success of the former arrangement, it is recommended that the installing contractor ensures that:

- The flushing is carried out in accordance with the procedures described in this guide
- The flushing and chemical cleaning procedures are planned so that the whole operation is carried out as a continuous process, ie there are no delays during the flushing stage, or between the flushing and chemical cleaning stages
- The cleaning specialist is allowed to satisfy himself that the flushing has been properly conducted and that the system is ready for chemical cleaning.

1.1.3 When to chemically clean

System cleaning will certainly entail thorough flushing with clean water, and may also involve the use of chemicals. Chemical cleaning is by no means a compulsory option for all systems, although the majority of systems will benefit from some form of chemical cleaning to supplement clean water flushing.
The type of clean will depend on consideration of the following factors:

1. System size - the amount of debris which could potentially be released into a system increases with the size of the system.

2. Whether the system is open or closed - closed systems will be less prone to, (although not immune from) the build-up of corrosion products.

3. System materials - systems using stainless steel, copper or plastic are less likely to contain corrosion debris.

4. Complexity of system and sensitivity of plant items - equipment such as chillers, small-bore control and regulating valves, low water content heat exchangers, and flow rate monitoring equipment, will be prone to blockage if dirt is allowed to accumulate in the system. Systems which use glycol-based anti-freeze are particularly sensitive.

5. Extension or modernisation of existing systems - whenever systems are modified or extended, it is beneficial to have the water quality in the existing system checked and any necessary remedial measures taken (as recommended by a cleaning specialist), before connecting to new plant or pipework. (Note that the procedures described in Sections 3 and 4 of this Guide are not suitable for application to old pipework.) Cleaning and treatment of existing systems (or new systems incorporating old pipework) should be as advised by a chemical cleaning or water treatment specialist (see also Section 5).

6. The length of the construction period - if the system is to be left exposed and damp for a prolonged period during the installation process, then this will increase the time for corrosion or biofilms to develop and will increase the need for chemical cleaning.

1.1.4 Specifying for system cleaning

The designer must provide adequate information, documented in the form of drawings, schedules and specifications to enable the pipework systems to be successfully cleaned. It is recommended that the advice of a cleaning or water treatment specialist be sought to assist in the preparation of this information.

The technical requirements of system cleaning should be developed by the designer, and water treatment advisor, to define clearly:

1. The scope of works, such as the systems to be cleaned, their functions, and method of operation

2. The scope and extent of the cleaning process, defining in outline the main stages to be included

3. The duties of the various parties (client, designer, main or managing contractor, installation contractor, commissioning engineer and chemical cleaning specialist) so there can be no doubt as to who is responsible for each activity.
4. The layout of the system in relation to the building form, to be shown on the design drawings, together with other engineering services where appropriate

5. The anticipated method by which flushing velocities are to be achieved, such as the pumping requirements and motor power requirement for temporary pumping facilities

6. Schematic diagrams and data sheets illustrating the design intent and including all the design information required to flush and chemical clean the system. (See Table 1 for example information needed)

7. Schedules of major plant, equipment and components as well as the schedules of materials, cross-referenced to the design drawings and schematic diagrams.

<table>
<thead>
<tr>
<th>Flushing flow rates</th>
<th>Mains</th>
<th>Branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sizes</td>
<td>Pipes</td>
<td>Strainer-basket mesh</td>
</tr>
<tr>
<td></td>
<td>Valves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>System volume</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dosing pots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filtration/separation equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drains</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incoming mains water</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:**
Example of design information required to flush and chemical clean the system.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Isolating valves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dosing pots</td>
</tr>
<tr>
<td></td>
<td>Sensitive equipment such as fan coil units, control valves, filters, and strainers</td>
</tr>
<tr>
<td></td>
<td>Dead-legs and dirt pockets</td>
</tr>
<tr>
<td></td>
<td>Effluent disposal points</td>
</tr>
<tr>
<td></td>
<td>Drain points</td>
</tr>
<tr>
<td></td>
<td>Quick-fill points</td>
</tr>
<tr>
<td></td>
<td>Air vents</td>
</tr>
<tr>
<td></td>
<td>Temporary pipework connections</td>
</tr>
<tr>
<td></td>
<td>Sampling points</td>
</tr>
<tr>
<td></td>
<td>Filtration/separation equipment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drawing reference identifications</th>
<th>Terminal units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Branches</td>
</tr>
<tr>
<td></td>
<td>Valves</td>
</tr>
<tr>
<td></td>
<td>Flushing valves</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperatures Pressure</th>
<th>Full range of system operating temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means of pressurisation</td>
</tr>
<tr>
<td></td>
<td>Maximum system operating pressure</td>
</tr>
<tr>
<td></td>
<td>Test pressures of pipework and pressure vessels</td>
</tr>
<tr>
<td></td>
<td>Relief valve settings</td>
</tr>
</tbody>
</table>
The specification of management requirements must be related to specific contractual conditions. Although the designer will strongly influence whether the cleaning specialist is to be involved with the main, managing or installing contractor, it is the latter who will determine:

- Forms of contract
- Programme constraints
- Resource levels
- Method statements
- Quality assurance procedures
- Site establishment details
- Compliance with site safety
- Compliance with industrial relations protocol
- Bonds, warranties and guarantees.

The different sources of project information required to fully specify system cleaning should not, however, preclude the early appointment of a cleaning specialist. The specialist could be involved on a consultancy basis during the design stage, converting to a sub-contractor later.

### 1.2 System Chemistry

#### 1.2.1 System Contaminants

The main contaminants found in water systems are:

**Installation Debris**

Water systems can pick up many extraneous materials which inadvertently find their way into systems during manufacture, storage and installation of the components. These include millscale, welding slag and metal swarf which can usually be removed by thorough clean-water flushing. Those which are not so easy to remove include cutting oil, soldering flux, jointing compounds and grease. Good handling and storage of pipework, and good plumbing practice during installation should be encouraged to limit the ingress of debris and dirt.

**Scale**

Scale is a build-up of solid material which normally occurs on the internal heat-exchanger surfaces in boilers or condensers. Scale is a dense, adherent deposition of mineral particles which are tightly bound to each other and to the metal surfaces. Calcium, magnesium and iron salts such as calcium carbonate, calcium sulphate, magnesium carbonate and magnesium silicate are the most common scales. Scale is formed when the water is heated or when the pH or alkalinity of the water is changed. The risk of scale forming is greatest with hard water and smallest with soft water. The hardness of water is related to the amount of calcium and magnesium salts present in the water. Scale is not a problem which affects new systems but can affect existing installations.
Corrosion products

Corrosion products are typical contaminants of water systems. There are two main causes of corrosion in steel pipework: electrolytic reaction and bacteria-induced corrosion.

The electrolytic reaction between metal surfaces connected through the presence of an electrolyte. In the case of a pipework system, the metal surfaces are connected by the electrolyte, water. The reaction which takes place involves the iron in the pipework combining with oxygen and hydrogen from the water, then further reacting with dissolved oxygen to form iron oxides.

Bacteria induced corrosion, such as sulphate-reducing bacteria, can induce corrosion under otherwise stable water conditions.

The principal factors influencing the rate of corrosion are temperature, the types and concentrations of impurities in the water, and the water flow rate. The chief chemical variables controlling the corrosive characteristics of water are its dissolved oxygen concentration, carbon dioxide content, pH and the amount of dissolved solids.

Biological fouling

The causes of biological fouling in water systems may be attributed to the source of the water, or the introduction of impurities during installation. Bacterial problems are common and can be difficult to predict.

Systems left filled but unused, or which are filled and subsequently drained, can quickly develop a biofilm layer on pipe surfaces. In the right conditions, certain types of bacteria may multiply and contribute to sludge formation and gassing.

The types of bacteria that cause problems are varied. Sulphate-reducing bacteria are the most destructive groups of biological foulants because they can cause corrosion resulting in severe localised pitting of pipework surfaces.

During the late 1990s, some bacteria (particularly *Pseudomonas*) were linked to a series of damaging contamination problems. The symptoms included blockages at valves and strainers, sludge formation, and severe gassing affecting flow measurements and commissioning results.

There is no evidence to confirm that *Pseudomonas* is responsible for these problems – other bacteria may be to blame. However, it has been found that where *Pseudomonas* levels are high, the danger of contamination is increased. *Pseudomonas* levels are, therefore, increasingly used as an indicator of the biological quality of system water.

1.2.2 Choice of chemicals

There are many different chemical products on the market which may be used for the removal or containment of system contaminants. Many of these will be mixtures or formulations of a specific group of chemicals with proven ability for the purpose. The chemicals may be categorised, depending on their application and nature, in Table 2.
Table 2:  
Chemical categories.

<table>
<thead>
<tr>
<th>Agents</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degreasing agents</td>
<td>To remove grease or oil</td>
</tr>
<tr>
<td>Inhibited acid cleaners</td>
<td>To remove surface oxides</td>
</tr>
<tr>
<td>Formulated products</td>
<td></td>
</tr>
<tr>
<td>Biocides</td>
<td>To remove biofilms and reduce bacteria levels</td>
</tr>
<tr>
<td>Biodispersants</td>
<td></td>
</tr>
<tr>
<td>Passivators</td>
<td>To minimize the rate of corrosion and control bacteria</td>
</tr>
<tr>
<td>Corrosion inhibitors</td>
<td></td>
</tr>
<tr>
<td>Biocides</td>
<td></td>
</tr>
</tbody>
</table>

Some chemical products could be a combination of chemicals from more than one of these categories.

The particular chemicals which might be used for cleaning are identified in Section 4, Chemical cleaning procedures.

1.2.3 Typical stages of a clean

A typical chemical cleaning programme is likely to include some, or all of the following procedures:

1. Static flushing
2. Dynamic flushing
3. Degreasing
4. Biocide wash (for systems at risk from bacteria)
5. Removal of surface oxides (for systems with mild steel components)
6. Effluent disposal/final flushing
7. Neutralisation (for inhibited acid cleans only)
8. Passivation

The static flush usually takes place after pressure testing as described in Section 2.4, Procedure for filling, pressure testing and static flushing.

A typical dynamic flushing procedure is described in Section 3, System dynamic flushing.

Descriptions for each of the chemical cleaning stages are provided in Section 4, Chemical cleaning procedure.

1.3 Pipework system design

The designer must ensure that the pipework system is designed in accordance with the relevant parts of the CIBSE Guides. Under operating conditions, a positive pressure must exist at all times in all parts of the system.

To facilitate flushing and cleaning the designer must ensure that the pipework system includes basic fittings and items of equipment to facilitate the process. The designer must therefore have a basic understanding of the objectives of system cleaning and of the intended cleaning procedure.
1.3.1 General provisions

Sizing of mains water supply

The flushing water supply pipe should, in the absence of any other priorities, be sized such that the minimum flushing flow rates in the system can be achieved without the need to interrupt the process while break tanks re-fill. Appropriate mains-water pipe sizes can be related to system volumes. Table 3 gives recommended sizes. A pressure of approximately 1.3 bar should be provided at the top of the building to ensure that flushing volumes are achievable.

A dedicated mains supply, adequate for the purpose, should be provided for system flushing where possible.

<table>
<thead>
<tr>
<th>System volume (litres)</th>
<th>Minimum mains size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2000</td>
<td>25</td>
</tr>
<tr>
<td>2000 – 10 000</td>
<td>40</td>
</tr>
<tr>
<td>&gt;10 000</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 3: Recommended incoming water main sizes.

Regulating valves

Regulating valves must be sized in accordance with CIBSE Commissioning Code W such that at the design flow rate, the valve is not less than 25% open. If valves are closed beyond this point, they may be prone to blockage.

Achieving recommended flushing velocities through some high resistance valves (typically 15 mm diameter low-flow valves) may be impractical. The temporary high-head pumps, required to achieve recommended flushing velocities, may be expensive or simply impractical to accommodate on some sites.

This problem can be avoided if low-flow regulating valves and their associated flow measurement devices are bypassed during the flushing and cleaning procedure.

Dead legs

The system should be designed to eliminate dead legs. In the few situations where this may be unavoidable, suitably sized drain valves should be incorporated at these points to facilitate draining and flushing. Dead legs that have a length of more than three pipe diameters should be looped to allow effective cleaning in full bore, up to and including 50 mm diameter pipework, and 50% bore above 50 mm diameter. These loops should incorporate a valve so that they can be shut off to allow increased flushing velocities in other parts of the system.
Pre-commission cleaning of pipework systems

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SECTION 1 DESIGN CONSIDERATIONS

Pressurisation units

Pockets of stagnant water trapped in the expansion vessels of pressurisation units have been found to provide potentially ideal conditions for bacterial growth. Consideration should be given to the use of units with re-circulating circuits, so that stationary pockets of water are avoided.

Strainers

Strainers should have a basket capable of withstanding the maximum pump head without distortion. Pressure test points should be provided on both sides of all strainers so that the pressure drop can be monitored. Drain valves are recommended on the flanges and/or end caps of Y strainers to facilitate local draining of the strainer body and adjacent pipework prior to basket removal and back-flushing of the strainer. The mesh size of the strainer basket should be selected with regard to the particular application and with reference to the manufacturers’ recommendations.

Pressure test points

Pressure test points in pipework and measuring devices should preferably be located at the side of pipework systems, not at the top or bottom where they can become air locked or act as dirt pockets. This may necessitate installing valves and fittings so that their test points are at the side.

Air vents

Air left trapped or circulating in pipe systems may cause the following problems:

- Noise at pumps and spring operated regulating devices
- Frothing or foaming (sometimes referred to as the champagne effect)
- Non-repeatability of flow measurements
- Inefficient operation of system pumps due to reduced energy transfer between the pump impeller and circulating water
- Increased rates of corrosion in steel pipework due to high oxygen levels.

The design should therefore incorporate features to facilitate the removal of air. In general, air vents should be provided on flow and return pipework at the ends of each horizontal run, and at the tops of each self-draining section.

During system fill, staggered flow and return legs (where either the flow or return connection to the riser is above the highest point in the run-out) can help to minimise trapped air pockets in terminal units, and other raised sections. This principle is illustrated in Figure 1.
During system operation, the water velocity passing air vent connections must be in the range 0·2 – 0·4 m/s. In this range, bubbles move steadily along the tops of pipes and will enter air vent connections. At velocities above 0·4 m/s bubbles may be drawn into the centres of pipes, and be carried past the air vent connections. Below 0·2 m/s bubbles may stop moving altogether.

The rate at which water will enter a pipework system and drain away from it is also influenced by the venting provision. Air vents of a minimum size of 25 mm should be installed at the tops of large flow risers to ensure that the system will fill or drain in a reasonable time.

**De-aerators**

Water in closed-circuit systems may contain significant amounts of dissolved air. This can be a major contributing factor to on-going system corrosion, and may also encourage biological growth.

De-aerators work by removing dissolved gases from the water. In doing so, the water is rendered unsaturated so that it will readily dissolve any remaining trapped air pockets in the system.

De-aerators remove dissolved gases when they temporarily come out of solution due to temperature or pressure variations. The higher the temperature of the water, or the lower the pressure, the less dissolved gas it can support.

Temperature differential-based de-aerators are, therefore, typically located at the hottest parts of systems, for example at the outlets from boilers, or at the inlets to chillers.
Pressure differential de-aerators are more versatile and can be positioned at any point in the system. They work by drawing off a small volume of water around which a near vacuum is created so that dissolved gases are released. The water is then reintroduced to the system and the process repeated.

De-aerators can be installed on a temporary basis to resolve problems in systems where venting is particularly difficult. They may also be installed as permanent features to help remove air entering via open tanks or due to system drain-down.

**Plant and equipment isolation and bypassing**

The system should be designed to enable the isolation and bypassing of all sensitive plant and equipment items such as boilers, chillers, heating and cooling coils, terminal units, control valves, low-flow and regulating valves, during the course of the flushing and cleaning operation. Fixed, full bore bypasses should be provided as close as possible to the plant items they are protecting. Bypasses should incorporate isolating valves to prevent short circuiting during subsequent normal plant operation.

Any decision to flush or chemical clean through sensitive plant items (for whatever reason) must be approved by the chemical cleaning specialist and plant manufacturer.

**Pumps**

The pipework immediately upstream of pumps should be easily removable so that the inlet and impeller can be inspected prior to pump start-up. The actual pump connections should be via flanges or proprietary mechanical couplings.

**The use of system pumps for dynamic flushing**

With all terminal units and high resistance control or regulating valves bypassed, the minimum flushing velocities recommended in Section 3.1.1 of this Guide will, in most cases, be achievable by one of the following methods:

- The system duty pump operating by itself
- Stand-by and duty pumps operating together
- Stand-by and duty pumps operating together with a temporary flushing pump installed in series or parallel.

The pipe and pump sizing calculations should reveal which of these three options is necessary.

Note that on some sites it may be difficult to accommodate temporary high head pumps for flushing purposes and, for this reason, the use of system pumps is often the preferred solution.
Provided that strainers are installed upstream of system pumps to prevent damage from large particles, their use for flushing should usually be acceptable. Water containing high quantities of fine particulate matter can sometimes cause erosion of pump seals. It may therefore be advisable to replace pump seals on completion of the cleaning process.

When considering the pumping options, care should be taken to ensure that the minimum net positive suction heads (NPSH) of pumps are maintained under flushing conditions, so that the danger of cavitation is avoided.

**Drainage**

The designer should ensure that there are adequate foul drains within close proximity to the flushing points, which can be used for draining and flushing. Standard 100 mm foul drains are suitable for all points except the plant room, where larger drains may be required for systems incorporating pipework greater than 200 mm in diameter.

Where plant rooms are below the mains drainage system and the system discharge water needs to be pumped, a temporary or permanent drainage tank will need to be provided. A suitably sized submersible pump will be required to pump the equivalent of the flushing supply water volume imposed by the flushing supply rate.

**Chemical injection**

The designer will need to take into consideration the requirement to inject a relatively large quantity of chemicals into the system during the chemical cleaning operation. In most cases, it will be necessary to introduce chemicals, via a temporary tank, through a 25 mm female connection at a point on the suction side of the circulating pumps. If a sidestream filtration/separation unit is installed, it may be possible to introduce chemicals from this unit.

1.3.2 **Large bore pipework**

In circuits which incorporate pipes more than 100 mm in diameter (typically primary circuits with low loss headers), it may be difficult to obtain the required minimum flushing velocities. There may be limitations imposed by the capacity of the incoming mains supply and the available drainage outlets. In these situations it is advisable to specify for alternative measures to remove system dirt. In particular:

- The use of easily demountable, mechanical grooved joints on all pipework and equipment, so that sections can be easily dismantled and physically cleaned
- The installation of strainers or full-flow filters on the inlets to plant items
- The installation of dirt pockets along the length of flow headers to act as a trap for dirt particles
- The use of chemical dispersants to encourage particles into suspension at reduced velocities.

These techniques are particularly applicable to primary circuits.
1.3.3 Plastic pipework

Plastic pipework presents fewer dirt-related problems, as jointing methods are usually cleaner than for steel and copper and because there is no risk of corrosion. However, plastics can still suffer from biofilm formation, and may take on a layer of iron oxides if they come into contact with dirty water from steel pipework in the same system.

Therefore, unless plastic pipes can be kept permanently isolated from steel pipes throughout the pressure testing, flushing and chemical cleaning procedures, the likelihood is that they will need to be chemically cleaned in the same manner as for steel pipes.

1.3.4 System facilities

Dosing systems

In order to maintain the cleaned system in the same condition after handover to the client, an on-going programme of water treatment will be essential. The introduction of water treatment chemicals should be via one of the following methods:

- A dosing pot, periodically filled with chemical quantities to the water treatment specialist’s instructions. Dosing pots must be pressure rated at a level compatible with the operating pressure of the system.

- An automatic dosing system which pumps chemicals into the system when the equipment senses a chemical deficiency in the water, or as a proportion of the make-up water.

Side stream filtration/separation

Side stream filtration or separation can be used as a means of reducing the quantity of water discharged to drain during the flushing. By diverting a proportion of the system circulating water through the filter (as little as 5%), solids in the flow are gradually removed. This arrangement is particularly useful on roof-top plant rooms where access to drains may be difficult.

The process may be monitored by a differential pressure measurement across the filter. When the entrained debris induces a sufficient pressure drop, the filter is back-flushed to drain. Once in place the filtration unit can be left to provide permanent protection to the system.

By removing nutrients from systems, side stream filtration can help to limit bacterial growth. However, the units themselves can provide ideal proliferation conditions if they are not regularly checked and cleaned. Filters of this type must therefore be easily maintainable.
Figure 2: Side stream filtration unit.

Hydrocyclones

Hydrocyclones are used to remove debris from a proportion of the total flow, although their use is primarily as a permanent protection to the system rather than as an aid to flushing. The inlet water enters the hydrocyclone tangentially and the spiral movement down the unit promotes a high centrifugal force to separate particles with a specific gravity above that of the water. As the solids are deposited at the base of the hydrocyclone out of the fluid stream, there is no increase in the resistance across the unit and minimal head loss. The solids reservoir may be manually or automatically cleaned using system pressure.
Full flow filtration

Where a cleaning specialist may have difficulty cleaning a system thoroughly, protection should be provided by installing permanent, full-flow duplex filters. In these cases, all of the system flow passes through the filter. A duplex filter is the most appropriate solution as the filters can be cleaned without the need to shut down the system.

1.3.5 System schematic

Figure 4 represents a typical hydraulic circuit for a building served by low level primary plant. The system incorporates both primary and secondary circuits serving vertical risers and terminal equipment fed via horizontal distribution mains.

Suitable provisions have been made within the system for filling, venting and subsequent draining of each sub-system. These features are highlighted in the following explanatory notes for each of the system sub-divisions (Details A - G).
Figure 4: Typical system schematic
1. All primary heat exchangers or generators such as boilers, chillers and major batteries should be protected by local strainers fitted as close as possible to the water inlet connection and provided with a means of local isolation.

2. For flushing purposes, the bypass should be line size to minimise pipework resistance at flushing velocities. For multiple chiller installations, the bypass resistance should be balanced with the chiller resistance. This will assist during maintenance operations by allowing individual chillers to be isolated without disrupting the flows to the others. For this function, the isolating valve would be replaced by a regulating valve.

3. Pipework and fittings immediately adjacent to primary heat exchangers should be readily demountable to facilitate visual inspection of the inner surfaces of the heat exchanger.

4. Adequately sized drain connections for flushing and cleaning purposes should be fitted on both sides of the heat exchanger.
1. The fill point from the temporary flushing tank, should be sized in accordance with Section 1.3.1, Table 3. The inlet point should be located downstream of the strainer close to the pump. If the inlet is located upstream of the strainer there is a danger of cavitation due to the potentially high pressure drop across a dirty strainer.

2. The chemical dosing pot should be isolated during the flushing and cleaning process. The addition of any chemicals for cleaning purposes should be via the open flushing tank indicated in Detail C.

3. Blank flanges or removable caps should be fitted to the ends of primary headers to facilitate dirt removal.

4. A manual air vent should be provided on horizontal headers where system filling may be a problem.

5. Connection to the pump may be taken from the side of a full-bore dirt pocket, to provide additional protection to the pump from contaminants.

6. The metering of water into the system may help determine the correct dosing levels for chemicals during on-going maintenance. It will also help to establish whether water is being drained from the system.
1. The temporary flushing tank and associated pipework are an optional means by which the system can be replenished with water and chemicals injected during the cleaning stages. The tank may be removed when the process is complete.

2. The use of a filtration/separation unit is recommended for a minimum of three months after the chemical cleaning and passivation processes are completed. This is in order to remove any residual system contaminants. The unit may be left in place to help maintain the system in a clean state throughout its operating life.

3. The metering of water into the system during the chemical clean may help determine the correct dosing levels for chemicals.

4. Secondary flow and return mains should be taken from the tops of headers to limit the passage of dirt from the primary into the secondary circuits.

5. In some cases it may be advisable to avoid flushing contaminated secondary water back into the primary pipework. For this reason flushing drain valves should be provided at the base of the secondary circuit take-offs.
1. A combination of two strainers should be used to provide total protection for the three-way mixing valve, measuring station and associated double-regulating valves.

2. A means of manually overriding the automatic control of the three-way valve should be provided so that, during the flushing and cleaning processes, raw water or chemicals can be drawn in via the primary injection circuit.
1. To prevent the ingress of contaminants, connections to terminal units should ideally be taken from the top of the main, or at an angle of 45 degrees to the vertical, but never from the side or bottom. Terminal connections of 15 mm or less do not generally require the fitting of vents and/or air bottles because they are effectively self-purging.

2. To prevent system blockages, horizontal distribution mains should not be sized below 20 mm.

3. The end-of-line bypass valve should be a full-bore line-size valve.

4. To release air during system filling, each pipework section should contain manual air vents at the end of each flow and return main. In order to trap air circulating with system water, the water velocity passing the connection to the air vent should be in the range $0.2 - 0.4 \text{ m/s}$. 

5. The flushing bypass should be line-size and must be located upstream of control valves and regulating valves, and as close as possible to the terminal unit. It is particularly important to avoid the need to flush through high resistance low-flow regulating valves since these may prevent the achievement of acceptable flushing velocities. Materials downstream from the flushing bypass will be excluded from the chemical clean, and should therefore, ideally, be constructed from non-ferrous materials, such as copper or from plastic.

6. Drain valves should be installed on flow connections to terminal units to facilitate back-flushing of the units.
1. Major terminal heat exchangers should be protected by local strainers which provide the additional function of protecting the three-port valve, measuring station and double regulating valves.

2. The flushing bypass valve should be a full-bore line size valve. The bypass line should be located as close as possible to the heat exchanger and associated control valve, and must be upstream of the means of isolating the battery and valve assembly. This will prevent any contaminated water from entering the battery during the flushing process.

3. The drain valves local to the battery should be as large as possible to facilitate local back-flushing of the battery to drain. This operation should be carried out using clean, inhibited water, following the chemical cleaning and dosing of the remainder of the system. An inspection should be made prior to connection of the battery to ensure that the plant item is free from internal contaminants.
1. Air vents and associated pipe connections are to be line size up to 25 mm, then 25 mm minimum for all larger pipes.

2. The bypass ensures a continual flow of low velocity water to the air vent. The regulating valve should be adjusted to achieve a velocity between 0.2 m/s and 0.4 m/s past the air vent connection. The valve should be installed on the inlet to the air vent in order to minimise the static pressure and encourage air to be released.

3. The automatic air vent would be isolated during normal system operation.

4. Air vent connections must be located with at least two diameters of horizontal pipe upstream in order to give bubbles time to settle to the top of the pipe.

5. Adequate clearance must be left above the finished floor level to facilitate the coupling of flexible full-bore drain hoses – typically 300 mm minimum.

6. Dirt pockets should be at least five diameters in length and contain a full bore isolating valve to enable them to be isolated and cleaned.
1.4 INSPECTION AND WITNESSING

The overall success of a system clean is dependent on the thoroughness of each individual stage of the clean. Inspection and witnessing of the cleaning method should be conducted as the work is in progress. With reference to the cleaning stages defined in Sections 3 and 4 of this Guide, the following activities listed will be required to demonstrate the success of the system clean.

1. One week before pressure testing

Take samples from the flushing fill-water connection to the system. Test the samples for total viable counts (TVC), *Pseudomonas*, and sulphate reducing bacteria. Interpret the results (taking advice from a chemical cleaning specialist) in accordance with Table 4.

2. One week before commencing of flushing and chemical cleaning

If the system contains water and has done so for a period of more than two weeks, then this water should be sampled and tested for TVC, *Pseudomonas* and sulphate-reducing bacteria levels. The results should again be interpreted (taking advice from a chemical cleaning specialist) in accordance with Table 4.

3. During both flushing stages

Witness flushing velocities, and the cleanliness of strainers and dirt pockets in all parts of the system. A sample of any material extracted should be retained for future reference.

4. On immediate completion of the pre-chemical clean dynamic flush

Carry out:
- A visual inspection of the water to confirm cleanliness
- A soluble iron test. The soluble iron concentration of the system water must not exceed 5 mg/l.

5. On completion of the chemical clean

Carry out:
- A visual inspection of the pipework surfaces (by removal of a specially prepared, easily demountable section of pipe).

6. On completion of the chemical clean, and after the final fill and addition of corrosion inhibitors and biocides

Carry out:
- Routine checks on strainers to ensure that particles collected are minimal
- Random sampling of the system water for chemical testing. Water should be taken from representative system extremities and low points. At an agreed position in the system, samples should be taken for record purposes, one to be kept by the client, and one to be kept by the cleaning specialist. The results from all samples must lie within the following limits:
  - **Total alkalinity (mg/l CaCO₃):**
    - As recommended by the chemical cleaning/water treatment specialist.
  - **Chloride (mg/l Cl):**
    - No higher than in incoming mains water (or as specified).
Sulphate (mg/l SO₄):
Equal to that of incoming mains water.

Total dissolved solids (conductivity- microSiemens):
As recommended by the chemical cleaning/water treatment specialist.

 Suspended solids (mg/l):
Less than 30 mg/l.
(NB: This value allows for the fact that the addition of corrosion inhibitor will cause an increase in the amount of suspended solids in the system.)

pH:
depending on water treatment method

Soluble iron (mg/l Fe):
Less than 5 mg/l.

Total iron (mg/l Fe):
Less than 15 mg/l.

Chemical inhibitor levels:
As recommended by the chemical cleaning/water treatment specialist.

7. One week after completion of the system clean and final dosing
Test for bacteria levels and interpret the results in accordance with Table 4. Water samples should be taken from representative system extremities and low points.
(NB: For the samples to be indicative of the success of the clean, the system water must be routinely circulated during the preceding week, and system integrity must be maintained (ie there must be no loss of water from the system). The introduction of fresh water during this period could re-introduce contamination.)

After satisfactorily signing off the system after Stage 7, responsibility for the future maintenance of system water quality must immediately be allocated to a suitable organisation. Failure to monitor water conditions, or to allow uncontrolled draining and alteration of the system, may result in rapid deterioration of the system water quality.
Table 4: Interpretation of results from bacterial analysis in closed circuit systems.

<table>
<thead>
<tr>
<th>Result</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVC at 22°C and 37°C ≤ 10 000 cfu/ml AND Pseudomonas &lt;10 cfu/ml AND Sulphate-reducing bacteria absent</td>
<td>The water quality is acceptable. Continued routine monitoring is required.</td>
</tr>
<tr>
<td>TVC at 22°C and 37°C ≤10 000 cfu/ml AND Pseudomonas between 10 – 50 cfu/ml AND Sulphate-reducing bacteria absent</td>
<td>The water quality is acceptable. Increased monitoring may be required to establish if there is an upward trend in bacteria levels. Biocide dosing may also be advisable, depending on the timing of the most recent dose. The chemical cleaning specialist should advise.</td>
</tr>
<tr>
<td>TVC at 22°C and 37°C &gt;10 000 cfu/ml OR Pseudomonas &gt;50 cfu/ml OR Sulphate-reducing bacteria present</td>
<td>Action may be necessary. The chemical cleaning specialist should advise.</td>
</tr>
</tbody>
</table>

* colony forming units per millilitre

Conditions:
Sample volume must be at least 100 ml. Samples must be stored at a temperature between 6-8°C and must be tested within 24 hours of being removed from the system. Tests should be performed by a UKAS accredited laboratory. Test results must be interpreted making allowance for the accuracy of test procedures. Any variation in results from samples taken at different points around the system should be investigated and, if necessary, further samples taken.

NB: The advice given in this table is based on practical experience of bacteria levels in real systems, and has not been validated by independent testing. The interpretation of results cannot, therefore, be viewed as definitive but is considered to be the best advice available at the time of writing.
2 INSTALLATION CONSIDERATIONS

2.1 MANAGEMENT

2.1.1 General

The installer’s objective is to provide a water installation which is as clean as is practically achievable, and which meets the designer’s specified requirements for flushing and chemical cleaning. To achieve this, properly managed resources must be allocated to the process of constructing the system and preparing it for cleaning.

The installer must carefully study the contract documents to determine precisely the project requirements. The installer will need to answer the following questions:

- What system features and facilities will be required to enable thorough cleaning of the system?
- Who is to carry out system flushing and chemical cleaning (ie will the entire cleaning process be sub-contracted, or only the chemical clean)?
- How should the cleaning process be programmed in relation to system installation and commissioning activities?

2.1.2 Organisation and planning

Where the installer is responsible for chemical cleaning, the installer should select and instruct the chemical cleaning specialist at the earliest possible stage to ensure that the expertise is available in the planning and programming of the cleaning task.

Together they should:

1. Establish effective lines of communication between the chemical cleaning specialist and other parties involved.
2. Produce a set of working drawings that show the detailed provisions for incorporating the cleaning facilities. These drawings should show the details of temporary facilities required.
3. Review the contract documents to determine the requirements for chemical cleaning, taking nothing for granted and seeking clarification where necessary.
4. Acquire all necessary information from the designer.
5. Retain all documents and literature provided with each delivered item of equipment for use by the chemical cleaning and water treatment specialists and for inclusion in the operating and maintenance manuals.
6. Examine on site the basic system operating features relevant to chemical cleaning. A pre-commission cleaning check-list should be employed.
7. Determine the potential for partial or phased cleaning of a system and locate suitable isolating valves to prevent cross-contamination. Spading-off may be possible as a viable alternative to the permanent installation of valves. Progressive records must be kept of a staged cleaning process. Record drawings, marked up to indicate which sections have been flushed, will help to achieve this objective.

8. Prepare an outline method statement for the cleaning procedure (ie, the main stages of the clean). All site operatives involved in the cleaning process should be issued with copies of the method statement to ensure that everyone involved in the cleaning process has a clear understanding of their specific responsibilities.

9. Agree witnessing and reporting stages for confirmation that the system cleaning is being conducted in accordance with the agreed procedure, and that the results of the clean are acceptable (refer to Section 1.4).

10. Obtain approval from the local Water Undertaking for the disposal of contaminated flushing water, and in particular, for the disposal of cleaning chemicals. If approval cannot be obtained make preparations for removal of the waste by other means. (NB: Gaining approval is often a slow process and must be planned well in advance.)

2.1.3 Choice of chemicals

The decision regarding which chemicals are most appropriate for system cleaning, corrosion inhibition and bacteria control must be made by a chemical cleaning specialist (possibly acting as an adviser to the designer). In order to select the most appropriate chemicals for the particular site conditions and circumstances, the chemical cleaning specialist will need to know:

- The method of construction, ie fabrication and jointing methods (this will indicate the potential degree of contamination from excess jointing materials and installation debris).

- The materials of construction, eg for pipework, jointing compounds, gaskets, seals, valves etc (so that the cleaning specialist can ensure that any chemicals used will have no adverse effects on system materials).

- Whether prefabricated parts of the system have been pressure tested off site, and if so how long ago (if prolonged, this may indicate deterioration of internal pipe surfaces).

- The anticipated period between installation of the system and first fill (if prolonged, this may indicate deterioration of internal pipe surfaces).

- The anticipated period between first fill of the system and the start of the chemical clean (if prolonged, this may indicate deterioration of internal pipe surfaces).
• Whether the system has been previously dosed with chemicals, and if so what type and for what purpose (residues from previous chemical dosing may interfere with the action of new chemicals).

• Any known restrictions on the disposal of chemicals through public drains (approval must be obtained from the local water authority before chemicals can be flushed to drain; this may influence the selection of chemicals).

2.1.4 COSHH Regulations

Chemical cleaning can be a hazardous operation. It may involve the use of temporary equipment generating high pressures, and the application of sometimes relatively aggressive and toxic chemicals in a site environment which is notoriously difficult to control. Safety of plant and personnel is inevitably a major concern.

The COSHH Regulations require that the employers, ie the contractor and the chemical cleaning sub-contractor (including the self-employed), implement a number of measures in compliance with the Regulations. Under the COSHH Regulations, the employers must carry out suitable and sufficient assessments, so that all the necessary measures to control any “hazardous substances” can be implemented. Substances that are hazardous to health include any substances that are labelled as dangerous under the Chemicals (Hazard Information and Packaging for Supply) Regulations 2002, ie pesticides, chemicals generally, micro-organisms, dust and any material, mixture or compound used at work or arising from work activities that may cause harm to people’s health and well-being.

The assessments should cover the substances present, (and any other forms into which they may be transferred), what harmful effects they may have, what harmful substances are given off during their use, who may be affected by them, to what extent and period of time they are at risk, how the exposure is likely to happen and under what circumstances, and what precautions are required to be implemented in the event of an incident occurring.

In addition, these assessments should make reference to the Health and Safety at Work Act 1974 (as amended by the Consumer Protection Act 1986), and to the duty of care on people carrying out the chemical cleaning process, since the process itself could be hazardous rather than the substances.

Assessments must be completed and recorded before undertaking any chemical clean. This then enables them to be reviewed if substances, processes or other matters are altered at some later date. It is the employers’ responsibility to ask for COSHH assessments from contractors and specialists with overall responsibility of the site. No chemical clean should be attempted without full discussion of all the safety implications associated with using possibly hazardous chemicals on a customer’s site. The HVCA COSHH manuals provide assessment hazard sheets for many of the hazardous materials used during the installation of building services.
2.2 PIPWORK INSTALLATION

The installer of the system must ensure that care is taken to limit the amount of dirt entering the system during installation. He must also be aware of the preparation and pre-planning considerations necessary to ensure successful flushing and cleaning.

2.2.1 Materials storage

Careful storage of pipes and fittings can help to limit the ingress of dirt and debris.

Where possible, all material and components should be delivered in packaging supplied by the manufacturer or stockist. Pipework should be racked off the ground with all open ends capped. Pipework fittings including valves and strainers, should be stored on shelving off the ground with all outlets capped until required for installation.

2.2.2 Good installation practice

Good installation practice is an important precursor to the flushing and cleaning procedure. The following practices should be the minimum standard which is acceptable:

- Lengths of pipework and components should be inspected prior to installation and any contaminants removed. (NB: Pipe cleanliness is particularly important in view of increasing incidences of bacterial contamination linked to dirt and other nutrients in pipework.)
- Care should be taken to prevent the ingress of solder, hemp and jointing compounds into the pipework system.
- Whenever possible, the use of WRC-approved jointing compounds should be considered as these will not provide nutrients for bacteria.
- When jointing compounds and hemp are used, only the absolute minimum amount should be applied, especially at joints to sensitive control or flow measurement devices. Jointing compound should not be applied to copper compression fittings.
- Prefabricated sections of pipework and fittings, bench assembled prior to installation, should be inspected internally and any contaminants removed.
- Strainer drain points should not be over-tightened (particularly for small bore strainers in copper pipe), since the force required to open them may cause damage to adjacent pipework.

It has been known for terminal equipment to arrive on site containing internal contaminants such as grease. Terminal equipment should be visually inspected (preferably at works) to ensure internal cleanliness of the units.

Prior to any connections being made, particular care should be taken to ensure that all temporary devices for protecting equipment during transit and storage have been removed.
Vessels, plant items and pipework with open ends should be temporarily blanked off. Before final connections are made, a last inspection should be carried out to ensure that items such as tools and welding rods have not been inadvertently left within the system.

All cisterns and tanks should be protected during the installation phase of the works and thoroughly flushed prior to connection to the pipework system.

2.3 Preparation for flushing and cleaning

When preparing the system for flushing, consideration should be given to the following points:

2.3.1 Installation checks

Prior to filling the system, a thorough inspection of all pipework, fittings and plant should be made to ensure that the system is complete and watertight.

As a general rule, it is prudent to close all plant, terminal unit, and end of run bypass isolating valves before the initial fill of the system.

2.3.2 Drainage

Adequate drainage should be made available, often necessitating direct access to manholes. Drains should be tested for absence of blockages prior to use. Transfer from the flushing drain to the drainage point should be via large bore, heavy duty, reinforced flexible pipes. The use of clear plastic pipes assists the progressive visual inspection of water quality during the flushing process.

2.3.3 Mains water

An adequate supply of town mains water should be made available for flushing at high velocity. This should be injected into the pipework system via a flushing tank and temporary high pressure pump.

Recommended mains supply sizes for different system volumes are indicated in Section 1.3.1, Table 3.

Back-flow protection to a standard compliant with the Water Supply (Water Fittings) Regulations 1999 must be provided between the incoming mains connection and system fill point (see Section 2.4.1).

Temporary site mains, used to fill pipework systems, have been known to harbour large numbers of bacteria, which then contaminate filled systems. It is therefore recommended that all temporary mains are cleaned and chlorinated in accordance with BS 6700 before being used for system filling.

A biocide dosed, temporary supply of fill water will also help to reduce the risk of bacterial contamination. However, health and safety requirements need to be taken into consideration with the use of some biocides (see Section 2.4.1).
2.4 Procedure for Filling, Pressure Testing and Static Flushing

2.4.1 System filling

In order to minimise the risk of biofilm development and consequent bacteria-induced problems, it is advisable to delay wetting the system for as long as possible. Once filled, the system clean should ideally commence within 48 hours.

The rate at which the system fills will be dependent on the available fill pressure in relation to the system height and size. Air vents should be provided as described in Section 1.3.1.

The system will normally be filled by one of the following methods:

- Temporary connection from the mains in compliance with the Water Supply (Water Fittings) Regulations 1999. An acceptable connection is a verifiable backflow preventer with reduced pressure zone (commonly known as an RPZ Valve Assembly).

- Temporary connection from the fire hydrant pipework provided that permission is obtained from the Fire Authority, and relevant water company, in advance. (NB: Fire hydrant water should be sampled prior to use for system filling, in order to ensure that it does not harbour high levels of bacteria.)

- Installation of a temporary tank and pump arrangement.

To avoid problems associated with the adequacy or cleanliness of the supply, a temporary main for the sole use of the M&E contractor is preferable.

To help minimise the possibility of a bacterial problem, fill water can be treated with a biocide to minimise the risk of biofilm development. However, health and safety requirements must be taken into account regarding the choice of chemical, since there is a possible risk of contact with site personnel should the system leak or fail during pressure testing.

2.4.2 System pressure testing

Prior to the commencement of the cleaning procedure, the entire system must have been previously pressure tested with all terminal units isolated and with flushing bypasses opened.

If prefabricated pipework or equipment has been hydraulically pressure tested off site prior to installation, it may subsequently have developed an internal layer of corrosion. The chemical cleaning specialist should be notified of this possibility.

If there is to be a delay of more than 48 hours between pressure testing and the start of the cleaning process, systems are best left full of biocide dosed water. This will control bacteria levels and result in less corrosion than if the system is drained. The use of corrosion inhibitors in static systems is of limited value since, to be effective, they need to be continuously circulated. Where there is a possibility of freezing, the system may also need to be dosed with an anti-freeze. These chemicals will be removed from the system during the flushing stages of the cleaning procedure.
2.4.3 Basic procedure

If the system is to be pressure tested in sections, then the following procedure applies to each section in turn.

1. Disconnect the sections of pipework immediately upstream of all pumps and inspect for any contaminants which could damage the impeller. Remove any such contaminants and refit the pipework section.

2. Open sufficient isolating valves as are necessary to fill and vent the primary ring-main, secondary risers and horizontal distribution mains. All terminal units and major plant items must remain isolated, with bypasses and/or loops opened.

3. Fill the system with water (dosed with biocide if possible – see Section 2.4.1) and vent the system mains.

4. With all terminal units and plant items still isolated, pressure test the system.

5. Leave the system charged for 48 hours to soften any inclusions.

6. Drain the entire system through the full-bore outlets and clean out all dirt pockets and strainers.

7. Refill and drain the system using clean water at least two more times, checking dirt pockets and strainers each time.

8. If the system is to be left for a period of more than 48 hours before the commencement of dynamic flushing, the system should be re-filled with biocide dosed water. If the system is to be left for a prolonged period, an anti-freeze chemical may be required.
3 SYSTEM DYNAMIC FLUSHING

3.1 FLUSHING OBJECTIVES

The main objective of the flushing process is to remove as much dirt and debris from the pipework system as possible in order to reduce the likelihood of system blockage and to create the best possible circumstances for a successful chemical clean and subsequent water treatment regime. The level of cleanliness achievable by system flushing is very much dependent on the adequacy of the system design and installation with regard to flushing. Provision should be included in the system for adequate air venting, draining and bypassing of equipment as detailed in the preceding design and installation sections of this Guide.

3.1.1 Importance of water velocity

The water velocity required for flushing must be sufficient to pick up and carry the majority of the dirt and debris in the system. Although it is quite feasible for much larger particles to find their way into systems, most of the debris will be below 5 mm in diameter.

Table 5 indicates the minimum flushing velocities required to pick up and move uniform shaped steel particles up to 5 mm in diameter along various sizes of horizontal pipes.

The specified minimum flushing velocity should be that indicated in the table, or the design velocity plus 10%, whichever is the greater. The flushing velocity must be selected based on the largest pipe size in the system or circuit to be flushed.

An explanation for the derivation of these values and its application to alternative pipe and particle sizes is included in Appendix A to this Guide.

Where achieving the recommended minimum flushing velocities in large bore pipes is impractical, consideration must be given to alternative methods of cleaning as described in Section 1.3.2.

<table>
<thead>
<tr>
<th>Nominal pipe size (mm)</th>
<th>Flushing velocity (m/s)</th>
<th>Flushing volume (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.96</td>
<td>0.20</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
<td>0.37</td>
</tr>
<tr>
<td>25</td>
<td>1.03</td>
<td>0.60</td>
</tr>
<tr>
<td>32</td>
<td>1.06</td>
<td>1.08</td>
</tr>
<tr>
<td>40</td>
<td>1.08</td>
<td>1.49</td>
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<td>2.45</td>
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<td>4.25</td>
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<tr>
<td>80</td>
<td>1.17</td>
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<td>10.47</td>
</tr>
<tr>
<td>125</td>
<td>1.24</td>
<td>16.41</td>
</tr>
<tr>
<td>150</td>
<td>1.26</td>
<td>23.98</td>
</tr>
</tbody>
</table>

Table 5: Minimum water velocities required to move 5 mm diameter steel particles in horizontal medium grade steel pipework.
3.2 Dynamic flushing procedure

3.2.1 General considerations

All items of plant which are sensitive to sediment must remain valved-off and bypassed throughout the flushing procedure.

Care should be taken to ensure that pumps are not allowed to operate against a closed head for prolonged periods. The situation should be avoided whenever possible.

3.2.2 Basic stages of a flush

The procedure for system flushing should follow the main stages described in Sections 3.2.3 to 3.2.7. The flushing operation is demonstrated by reference to the system schematic in Figure 12. It is assumed that the procedures for filling, pressure testing and static flushing, as described in Section 2.4, have been completed, and that the system is filled and ready for dynamic flushing.
Figure 12: Valve reference numbers.
3.2.3 Dynamic flushing of primary ring-main circuit

In order not to circulate around the entire system any contaminants which may have gravitated to the larger bore pipework, the primary ring-main is dynamically flushed first. The primary ring-main is likely to be the area where recommended minimum flushing velocities are most difficult to achieve. Parts of the primary circuit may therefore have to be cleaned by one of the alternative measures described in Section 1.3.2.

Example Procedure

1. Isolate the secondary circuits by closing valves 3, 4, 5 and 6, and confirm that the major plant items connected to the primary ring-main are still isolated and bypassed.

2. Insert primary pump strainer baskets of perforation diameter not less than 3 mm.

3. Connect a reinforced flexible hose of adequate diameter to drain valve 1 and run the hose to drain.

4. Close isolating valve 2 and ensure all other valves in the primary circuit are open.

5. With the ring-main fully primed and vented, turn on the temporary flushing pump, gradually open drain valve 1 and adjust until the drain rate balances the mains flow rate into the flushing tank (Figure 13).

![Figure 13: Flush to drain with strainer isolated.](image)

6. Turn on the primary pump. Open isolating valve 2. Re-balance drain valve 1 until the drain rate again balances the mains flow rate into the flushing tank. Monitor the primary pump motor current to ensure that the full load current is not exceeded.
7. Circulate water around the primary ring-main for one hour and monitor the pressure drop across the pump strainer to ensure that the manufacturer’s recommended maximum pressure drop is not exceeded and pump cavitation problems are avoided (Figure 14).

**Figure 14:** Flush to drain with primary ring-main operational.

8. Measure the flow rate in the primary ring-main to determine the flushing velocity being achieved. Ask the client representative to witness the flow rate achieved, and record the value.

9. Run the pumps until the drain water runs clear.

10. Stop the primary ring-main pump. Stop the flushing pump and close valve 1 simultaneously. Isolate and clean the primary pump strainer.

11. Replace the strainer basket.

12. Repeat the process until the strainer no longer collects sediment.

### 3.2.4 Dynamic flushing of secondary mains pipework

In order to achieve the highest possible flushing velocity in the main secondary circuit pipework, the valves on all secondary sub-circuits must be fully opened to flow, so that the resistance at the pumps is as low as possible. During the flush a flow measurement should be taken at the flow measurement device in the main return to the secondary pumps. The value obtained should be witnessed by a client representative and recorded.

The secondary system water should normally be flushed back into the primary pipework header, and from there direct to drain. In some cases it may be desirable not to flush contaminated secondary water back into the clean primary pipework. The flushing water should then be drained at the base of the secondary circuit take-offs (valve 7), or at the base of the risers (valve 9). This would certainly be the case when the main
plant and primary circuit is installed in a roof-top plant room, and it is deemed impractical to flush particles back up a vertical return pipe.

Where a side stream filtration/separation unit is installed on the primary circuit, this can be used to remove system contaminants, thereby reducing the amount of water flushed to drain. The secondary water would be flushed back into the primary pipework and be circulated with the primary pumps until the side-stream unit has achieved the required cleanliness.

For the purpose of the following example procedure, it is assumed that the main proportion of the flushing water will be deposited to the drain.

**Example procedure**

1. Ensure that the valves isolating the secondary circuit connections to the primary ring-main are still closed, (valves 3, 4, 5 and 6).

2. Ensure that individual terminal units remain isolated and bypassed.

3. Ensure that all valves on the horizontal mains are fully open.

4. Remove the baskets from all of the strainers serving the horizontal mains (except for the strainer basket protecting the secondary pump which should remain in position). Remove or bypass constant flow regulators and “low-flow” regulating valves where fitted.

5. Ensure that the three-port mixing valve is in the full flow non-mixing position.

6. Turn on the flushing pump and the primary pump. Gradually open drain valve 1 until the outflow rate balances the maximum mains flow rate into the flushing tank. Simultaneously monitor the primary pump motor current to ensure that the full load current is not exceeded.

7. Open valves 3 and 5.

8. Turn on the secondary pump. Gradually adjust drain valve 1 until the outflow rate again balances the maximum mains flow rate into the flushing tank (Figure 15). Simultaneously monitor the secondary pump motor current to ensure that the full load current is not exceeded.

9. Monitor the pressure drop across the secondary pump strainer to ensure that the manufacturer’s recommended maximum pressure drop is not exceeded, and pump cavitation problems are avoided.

10. Measure the flow rate in the secondary mains to ensure that the specified flushing velocity is being achieved. Ask the client representative to witness the flow rate achieved and record the value (if the required flushing velocity cannot be achieved, turn on the stand-by secondary pump and allow both pumps to operate in parallel).
Figure 15: First flush through horizontal mains.
11. Run the pumps until the drain water is clear of contaminants.

12. Turn off the secondary pumps. Turn off the primary pumps. Turn off the flushing pump and simultaneously close drain valve 1.

13. Close valves 3 and 5.

14. Close all valves on the horizontal mains to each floor (valves 10, 11, 12, 13, 14, and 15).

15. Isolate and clean the primary and secondary pump strainers.

16. Isolate and clean the dirt pockets at the base of each riser, (valves 8 and 9).

### 3.2.5 Dynamic flushing of horizontal mains to each floor

The flushing procedure should start from the top floor and work down the building through intermediate levels to the ground or lowest floor. In order to achieve the specified minimum flushing velocity along the full length of the horizontal mains, it will probably be necessary to open the flushing bypasses to the terminal units in batches, starting from the end terminal and working back towards the riser. This is to prevent the water short circuiting the downstream pipe sections. (For reverse return systems, the units should be opened commencing with the unit closest in the direction of flow.)

A sufficient number of terminal unit bypasses must be opened to ensure that the required flushing velocity is achieved in the main pipe serving the floor. This essentially means opening a sufficient number of terminal unit bypasses, such that the total bypass pipe area is equivalent to the area of the main pipe onto the floor. For example, given the arrangement of terminals shown in Figure 16, the flush might start with only the bypasses to terminals 5 and 6 open. When this flush is complete, the bypasses to terminals 3 and 4 would be opened, and those to terminals 5 and 6 closed. Finally, bypasses to terminals 1 and 2 would be opened and those to terminals 3 and 4 closed. This will ensure that all sections of the horizontal main achieve their specified minimum flushing velocity.

A flow measurement should be taken at the flow measurement device serving the floor. The values obtained should be witnessed by a client representative and recorded.
**Example Procedure**

1. Set up the flushing condition by following the same basic procedure as described in Section 3.2.4 (stages 1 to 9), but with only isolating valves 13 and 14 serving the top horizontal mains, open to flow, valves 10 and 11 remain closed (Figure 17).

2. Close a sufficient number of terminal unit bypasses, such that the bypass pipe area is equivalent to the pipe area onto the floor.

3. Measure the flow rate in the pipework onto the floor to ensure that the specified flushing velocity is being achieved. Ask the client representative to witness the flow rate achieved and record the value. (If the required flushing velocity cannot be achieved, turn on the stand-by secondary pump and allow both pumps to operate in parallel.)
Figure 17: Forward flush through horizontal mains on top floor.
4. Work back along the system, closing and opening terminal bypasses until all sections of the pipework run have been flushed at the required velocity.

5. Continue the process until the drain water is free from contaminants.

6. Close valves 13 and 14 on the top floor and simultaneously open valves 10 and 11 to allow the water to flush through the horizontal mains on the next floor down (Figure 18).

**Figure 18:** Forward flush through horizontal mains on intermediate floors.
7. Repeat stages 2 to 5 until the cleaning process is complete.

8. Check the pressure drop across the primary and secondary pump strainers. (If necessary, turn off the pumps and clean the strainer baskets and dirt pockets.)

9. Turn off the secondary pump. Turn off the primary pump. Turn off the flushing pump and simultaneously close drain valve 1.

10. Isolate and clean the primary and secondary pump strainers.

11. Isolate and clean the dirt pockets at the base of each riser (valves 8 and 9).

12. Repeat the flushing procedure for each of the secondary circuits fed from the primary circuit header.

3.2.6 Final full system flush

If individual circuits or sections of pipe are left isolated for a period of time after flushing, the soluble iron level in the water will increase. To bring all parts of the system back within the limits defined in Section 1.4, the entire system should be flushed again simultaneously. The aim is to dilute and replenish the system water, and there is no need to measure flushing flow rates (Figure 19).
Figure 19: Final flush through entire system.
3.2.7 Reinstatement of terminal units and main plant items

Only after the primary and secondary circuits have been flushed, chemically cleaned (as described in Section 4), finally flushed and dosed with biocide and inhibitor should system water be permitted to enter terminal units.

All terminal units and plant items should have been isolated and bypassed during the pre-flushing and chemical cleaning stages. Assuming a hard bypass is included as advised in Section 1.3.1, then responsibility for reinstatement and back-flushing of the terminal units can be given to the cleaning specialist, or to the installing contractor under the supervision of a specialist.

Immediately after re-instatement to the mains pipework system, each unit should be back-flushed. It is assumed that the terminal units will have been visually inspected for internal cleanliness prior to installation, as recommended in Section 2.2.2. The purpose of back-flushing is therefore simply to remove the small amounts of loose debris which might collect in the units. Although the amount of debris likely to be found in any one terminal unit is not great, the accumulation of the deposits from a large number of units can cause problems.

Terminal units can be back-flushed, using the inhibitor and biocide-dosed system water, into a temporary vessel such as a bucket. If the units are fitted with constant flow regulators, these should be removed and temporarily replaced with a distance piece. Alternatively if they are cartridge type, it may be possible to remove the cartridges during each flush, then replace them afterwards.

The flushing of specified terminal units should be witnessed by the client representative. Any units blocked or partially blocked due to the excessive use of jointing compound should be reported back to the installing contractor.
4 CHEMICAL CLEANING PROCEDURE

4.1 INTRODUCTION

Chemical cleaning of the system should always be the responsibility of the appointed chemical cleaning specialist sub-contractor. However, in order to ensure that the chemical clean is successful, the installing contractor must be prepared to commit resources to assist with the process. In particular the installer will need to be aware of system conditions which must be maintained during the clean.

4.1.1 Importance of pre-flushing

Properly executed clean water flushing as described in Section 3 of this Guide, is an essential pre-requisite to any effective chemical cleaning programme.

Chemical cleaning should not be attempted unless the system has been thoroughly clean-water-flushed to the satisfaction of the cleaning specialist.

If a system contains significant amounts of loose installation or corrosion debris and flushing is not carried out before the chemical clean, then the result will be a high consumption of chemicals, while the cleaning effect will be minimal.

Chemical cleaning must be carried out immediately after the pre-flush (within 24 hours).

4.1.2 The importance of flow

Proper circulation in all parts of the system is essential to effect thorough cleaning within a predictable time scale. Proper system flow ensures that:

- Fresh cleaning agents are continually presented to the deposits, helping to speed up their dissolution
- The penetration of deposits by the chemicals is assisted by the mechanical action of the fluid flow
- The temperature of cleaning agents (and metal) are kept even around the system
- Insoluble material is kept in suspension and does not re-deposit in the pipework
- Accurate quality control is possible due to uniform sample availability
- Any gases produced due to the cleaning agent are carried to vent in the flow stream.

It must be noted that, for hydrochloric acid cleans, high flow rates must be avoided as this can result in a breakdown of the acid inhibitor film and may result in corrosion at impingement areas.
4.1.3 The importance of temperature

For some chemical cleaning operations, there will be a need to maintain certain minimum temperatures in the system. In heating systems the boiler may need to be reconnected to the system. A high temperature is usually needed to speed up the reaction of the chemicals and therefore reduce the cleaning period to an acceptable limit. The installing contractor may therefore need to ensure that boiler plant and controls are available to achieve the required temperature. In chilled water systems, if the optimum temperature cannot be achieved, the cleaning period may have to be extended.

4.1.4 Duration of chemical circulation within the system

The required chemical circulation time for a successful clean is usually between 12 and 72 hours, to run either continuously or intermittently (in 8 hour periods for example). The circulation period depends on the following operating conditions:

- Concentration of cleaning solution
- Ph of cleaning solution
- Temperature of cleaning solution
- The type of iron oxide deposits
- The types of non-iron oxide constituents in a deposit
- Thickness of deposit
- Surface condition (hard or soft) of deposit.

4.1.5 Disposal of chemicals

It is sometimes possible to discharge chemicals into foul water drains. Under no circumstances should chemicals be discharged into surface water drains.

Before any chemical can be discharged into the public drains, permission must be obtained from the local Water Undertaking. Application must be made and details given of the chemicals to be discharged, the maximum quantity, the maximum rate of discharge, the temperature, and the proposed date on which the discharge will take place.

Permission to allow the discharge will depend primarily on the nature of the chemicals. The chemicals must comply with the requirements of existing legislation, including the Control of Pollution Act 1974, the Water Act 1989, and The Trade Effluents (Prescribed Processes and Substances) Regulations 1989 amended by SI 1990/1629 and The Trade Effluents (Prescribed Processes and Substances) Regulations 1992.

Based on these directives, the Water Undertaking can specify the limits for temperature, pH and concentrations of substances which may be permitted for discharge. Effluents which do not meet these criteria will not be permitted.
In addition to an assessment of the substances in the effluent, the Water Undertaking must also take into account the size and condition of the local sewers and sewage works, together with the degree of downstream usage for the local rivers into which the treated effluent will eventually be deposited. As there is considerable re-usage of river water in the London area, this imposes greater restrictions on the quantities of chemicals permitted for discharge.

4.2 Cleaning options

There are a number of options for cleaning which arise due to the different categories of chemicals commonly used. Different chemicals may be used by different chemical cleaning specialists to achieve the same basic results.

A typical chemical cleaning programme is likely to include some or all of the following procedures:

- Static flushing
- Dynamic flushing
- Degreasing
- Biocide wash (for systems at risk from bacteria)
- Removal of surface oxides (for systems with mild steel components)
- Effluent disposal/final flushing
- Neutralisation (for inhibited acid cleans only)
- Passivation
- Corrosion inhibitor and biocide dosing.

Static and dynamic flushing, as described in Sections 2 and 3 of this Guide, are an essential pre-requisite to any system chemical clean.

4.2.1 Degreasing

If the internal pipework surface of the system is contaminated with grease or oil, it is important that this is removed to ensure that the subsequent chemical cleaning operations are successful. The most commonly used degreasing agents are mild alkali formulations, such as caustic solutions or detergents. These are used at various concentrations together with a wetting agent (surfactant) at system temperatures of up to 100°C. An alternative option would be to use an organic solvent.

4.2.2 Biocide wash

In order to control bacteria and biofilms which may become established inside pipework during the installation process, it is sometimes advisable to carry out a biocide wash as an additional stage of the chemical cleaning procedure.

In view of the increasing incidence of bacterial contamination, biocide washes are sometimes viewed as an essential precautionary measure to avoid the problem. However, a biocide wash may not always be necessary and the advice of the chemical cleaning specialist should be sought.
In general, there may be less need for a biocide wash when:

- Temporary fill mains have been disinfected prior to use for system filling
- There has been a pre-clean monitoring period during which water samples have shown low, stable (non-increasing) bacteria levels
- A bacteria resistant, wrc-approved compound has been used for pipework jointing
- A biocide has been added to all fill water (nb: dosed water used for pressure testing may raise health and safety problems – refer to section 2.4.1.)
- Incidences of bacteria related problems in the region or locality of the building are rare.

4.2.3 Removal of surface oxides

There are a number of different chemical processes used for this activity:

- Inhibited acid cleaning

- Formulated products, such as polymers, chelants, and other formulated products.

**Inhibited acid cleaning**

Acid cleaning involves the circulation of acid at low concentration and can be used for the removal of unwanted oxides and deposited scales from pipe surfaces. The most commonly used acids for the removal of oxides from ferrous materials are hydrochloric acid and ammoniated citric acid. Other organic acids may also be used for this purpose where availability and cost favour them.

Hydrochloric acid is not suitable where there are major components made of stainless steel. Ammoniated citric acid is recommended where austenitic steels or non-ferrous alloys are present. The monoammonium form of citric acid, neutralized to pH 3.5-4.0 has proved to be a useful solvent for iron oxides.

In all uses of acids for cleaning there is a risk of both general and localised pitting corrosion of the metal, once the removal of the oxide or scale has been achieved. Therefore, the action of the cleaning solution must be controlled by the addition of a suitable acid inhibitor. The appropriate acid inhibitor will be specific to the type of acid being used. The temperature may need to be kept within a set range necessary to minimise corrosion. Mixed with the acid before starting the clean, the acid inhibitor will not interfere in the chemical reaction between the deposit and acid, but will substantially minimise the reaction with good metal.

An example procedure for inhibited acid cleaning is included in Appendix B.
Formulated products

**Polymer cleaning**: Polymer cleaners, otherwise known as dispersants, act by creating repellent forces between individual particles in the solution; they are therefore able to break down the loose surface deposits on the pipework and ensure that they stay in suspension until the chemical is flushed away to drain. They differ from acids and chelant complexing agents in that they are not intended to dissolve the metal oxides. Treatment of steel pipes with polymers will leave the original hard layer of impervious magnetite, which will not deteriorate and which will offer some degree of protection against further corrosion of the metal underneath.

An example procedure for polymer cleaning is included in Appendix C.

**Chelants**: Oxides can be removed by application of chelant formulated agents, otherwise known as complexing agents.

Probably the most established example of a complexing agent is ethylene diamine tetracetic acid (EDTA).

EDTA is used to remove iron oxide from steel in either sodium or ammonium form, at pH 9·2. However, to achieve a practically useful rate of dissolution of oxide, the process has to be carried out at an elevated temperature and a correspondingly high pressure (typically 160°C and 5·5 bar) making it unsuitable for low temperature hot water heating systems, chilled and condenser water systems.

Under certain conditions, the use of complexing agents can lead to severe metal attack, including variable pitting. Therefore an appropriate inhibitor is usually used in conjunction with them.

**Other formulated products**: Formulated products, such as neutral pH-type cleaners, are usually a proprietary formulation consisting of different chemicals performing different functions. For example, a single product might contain organic wetting agents and detergents for degreasing, inorganic and/or organic corrosion inhibitors, reducing compounds and organic iron oxide removers.

For optimum performance of these products the system pH is controlled to a 6·5 - 7·0 pH band. As the system clean progresses, the dissolving iron deposits may liberate hydroxyl ions which gradually raise the pH of the cleaning solution and reduce the dissolving rate. A supplementary neutraliser product may therefore be employed to lower the pH and maintain optimum cleaning conditions.

A particular feature of some formulated products is that they can promote a passive metal surface which can be retained after the cleaning has been completed.

An example procedure for cleaning with a formulated product is included in Appendix D.
4.2.4 Effluent disposal/final flushing

The disposal of chemicals should be as agreed with the contractor in advance with due regard to the limitations outlined in Section 4.1.5.

All chemicals should be removed by clean water rinsing and flushing at this stage, so decreasing their corrosive effects by achieving neutral conditions, i.e., a pH value of approximately seven, depending upon the quality of the water used.

The procedure for final flushing must be devised and agreed by the cleaning specialist. The final flush may be a series of static flushes whereby the system is drained, refilled, and circulated a number of times. In most cases, however, it will involve a dynamic flush of the system, taking particular care to ensure that no dead-legs are left unflushed. When the system is dynamically flushed, the procedure used will be based on the principles described in Section 3 of this Guide.

The use of flocculants or dispersants during the final flushing stages may further assist in mobilising any loosely adherent particles.

4.2.5 Neutralisation

A neutralisation stage may be necessary if an inhibited acid cleaning agent is used. The final flushing will have removed the majority of the cleaning chemical, but to ensure that any isolated pockets of chemical are rendered harmless, an alkali solution may need to be introduced to the system. This may be a separate stage in the process, or it may be achieved by introducing an alkali water treatment chemical. The same chemical will then perform the functions of neutralising agent, passivating agent and corrosion inhibitor.

4.2.6 Passivation

After the system has been finally flushed, the pipework surfaces are left in an “active” state, i.e., they are clean and exposed and are particularly prone to further corrosion. Therefore, passivation of the exposed pipework surfaces must take place immediately after the final flushing in order to render the active metal surfaces passive. Passivation is achieved by introducing a passivating agent to the system. This may be a separate chemical or it may be part of the function of the water treatment corrosion inhibitor chemicals.

4.2.7 Corrosion inhibitor/biocide dosing

On completion of the chemical clean, the system must be dosed with corrosion inhibitors and biocides to help control the subsequent corrosion of the metal, and the possible development of microbiological growth. One week after dosing, samples of the system water should be taken for testing and for record purposes in accordance with Section 1.4.
Corrosion inhibitors

Although highly effective as a protection against corrosion in steel systems, nitrite-based corrosion inhibitors can, in certain circumstances, cause microbiological problems. Nitrite-reducing bacteria (including some *Pseudomonas* species) are able to use nitrite, thereby encouraging their multiplication while, at the same time, depleting inhibitor levels.

For this reason, molybdate-based inhibitors are sometimes recommended as alternatives to nitrite. However, they tend to be slower acting, resulting in higher iron levels in the final treated water. A blend of low level nitrite with molybdate is a compromise solution offered by some chemical cleaning/water treatment specialists.

Biocides

Biocides must be selected by the cleaning specialist to suit the system and the particular stage of system cleaning. Biocides may be dosed into static systems to prevent bacteria multiplying when there is a delay between pressure testing and the commencement of flushing and chemical cleaning (see Section 2.4.1). They may also be used in conjunction with biodispersants to kill bacteria and remove biofilms during a biocide wash. Finally after the final fill of the system they will be used to provide ongoing protection for the system against bacteria.

4.2.8 Treatment up to system handover

If the building is not to be put into normal (occupied) operation for a prolonged period, ie more than one week, then the system water should be regularly monitored and circulated during this time, and if necessary further dosed until the system is handed over and put into normal operation. This may also necessitate the inclusion of an appropriate anti-freeze, where there is a danger of the system freezing. If draining of the system, or part of the system, is unavoidable, one of the following protective measures must be taken:

- Dry out the system with hot air. This may be difficult if sumps exist in complex components and pipe runs.

- Fill the system with an inert gas such as nitrogen. All joints have to be gas tight to prevent gas losses.

The preferred measure will depend on the geometry of the system and the availability of equipment and materials.
4.3 **On-going water treatment**

Water treatment is necessary throughout the operating life of the system. The various options and considerations involved in the implementation of an effective water treatment regime are the subject of BSRIA Application Guide AG 2/93 *Water treatment for building services systems*.

The main considerations for chemical water treatment regarding the different system types are as follows:

1) **Condenser water (open) circuits**

   *NB. When treatment is applied to evaporative systems, recommendations regarding these treatments must comply with the requirements of TM13 2000 (CIBSE Technical Memoranda 2000: Minimising the Risk of Legionnaires’ Disease) and Legionnaires’ disease: the control of legionella bacteria in water systems: Approved Code of Practice and Guidance. Third edition, HSE Books, 2001.*

   Cleaned water circuits should be treated (dosed):
   
   - With inhibitors to limit corrosion and scale formation in the pipework
   - With dispersants to keep particles in suspension
   - With alternating biocides to reduce the incidence of legionella and to minimise the growth of algae and slime.

   Furthermore, softened make-up water may be required. Systems should also be periodically disinfected.

2) **Closed low pressure hot water heating and chilled water systems**

   Cleaned systems must be treated (dosed) with corrosion inhibitors and biocides to limit corrosion, scale, mineral sludge and bacterial slime formation in the pipework. Softened make-up water is desirable.

3) **Recirculatory humidification systems**

   Make-up water may require pre-treatment. Good housekeeping and maintenance are essential for this type of system.
5 CONNECTIONS BETWEEN NEW AND EXISTING SYSTEMS

To protect water quality when systems are extended or modified, newly installed pipes must be cleaned and treated before being connected to existing pipes. Similarly, the condition of water in existing pipes must be checked to ensure that it will not contaminate new, clean pipework.

If systems are properly checked before connection, disputes concerning the origin of water quality problems can be avoided.

5.1 Scope of clean required

If the proposed new works are small relative to the size of the existing system, then the cleaning process can be kept simple.

For example, where a small number of copper-fed terminal units are replaced or re-located with minimal draining of the existing system, then new pipework can simply be back-flushed with existing treated system water following the guidance given in section 3.2.7.

However, if the works involve draining existing mild steel pipes, then a full re-clean may be required. A re-clean is recommended unless the drain down lasts for less than eight hours and the system is immediately refilled with treated water and circulated. If the drained pipe sections are large relative to the size of the existing system, it is still advisable to re-clean the drained pipework.

5.2 Water sampling

Whatever the extent of the new works, the condition of water in the existing system must be established straightaway. Early sampling of water from the existing system will ensure that if the water quality is poor, the maximum possible time is available to carry out remedial treatment before the new works are ready.

If the installation period for the new works is prolonged, it may be necessary to check the water in the existing system several times to ensure that good water quality is maintained. Sampling for this purpose should be carried out by the installing contractor’s own water treatment specialist, and would be in addition to samples taken as part of the system owner’s maintenance regime.

Before any new pipework is connected into the existing system, the quality of water in the new system must also be demonstrated.

Water samples for both new and existing systems should be taken in sufficient numbers and appropriate locations so as to obtain a proper indication of the overall system condition. Appropriate locations might include drains around main plant items, system extremities, areas of low water velocity (such as terminal branches), or areas that may have been temporarily isolated.
To avoid potential confusion over the results of water analysis reports, the parties involved should agree in advance the water sampling regime to be implemented. This might include agreeing:

- The dates on which sampling will take place
- The locations from which samples will be taken
- The water properties to be analysed
- The person/company who will carry out the analysis
- The need for duplicate sampling (such as separate samples being taken by each party).

### 5.3 Shell and Core Type Projects

Where it is known that a system will be extended at a future date, such as in shell and core type projects, allowance should be made to facilitate connections between the main base-building system and future fit-out works.

#### 5.3.1 Provision for future extension

Figure 21 shows a typical pipe connection with allowance for future extension.

**Figure 21:** Branch connection showing provisions for future connection

Referring to the numbered features in Figure 21:

1. A temporary bypass between flow and return pipe connections prevents them from becoming dead-legs where dirt or bacteria could collect. The bypass should be full line size to create a low resistance path enabling the required flushing velocity to be achieved in base building pipework. A drain cock located in the temporary bypass will allow water samples to be taken.

2. A line-size double regulating valve may be installed in the bypass (if specifically asked for by the designer or building owner) as a means of simulating the future floor pressure loss around the fit-out works thereby avoiding the need for a re-balance of branch flow rates.
3. The future works must be terminated with isolating valves to facilitate final connection of the cleaned and treated system. When connected, the flow side isolation valve will act as downstream isolation for the strainer.

4. A visible air gap should be maintained at all times between existing and future works so that no confusion can arise as to whether the two systems are connected or not. The gap will eventually be filled with a short section of pipe (commonly referred to as a spool piece). To avoid the need for long and unwieldy spool pieces, the distance between new and existing pipework should be kept as short as possible, while ensuring adequate space for the required valve arrangement and the connection of pipework and hoses to temporary pump.

5.3.2 Temporary pump sets

A temporary pump set will be needed to circulate chemicals and achieve flushing velocities in new circuits which do not have their own pumps.

The temporary pump should be sized such that it can achieve the flushing velocity specified in Table 5, section 3.1.1, (or the design velocity plus 10%, whichever is the greater). The system designer or installing contractor should be able to provide values for the design flow rate and pressure loss through the new system.

Suitable locations for temporary pumps should be identified which are away from emergency exit routes but within reach of electrical, water supply and drain facilities. All temporary pump sets should have surrounding protection barriers, and should be located in bunds to assist with water collection in the event of a leak.
Figure 22 shows typical provisions in a temporary pump set.

**Figure 22: Temporary pump arrangement.**

Referring to the numbered features in Figure 22:

1. Flexible pipe between the temporary pump and system is acceptable for short periods. However, if the temporary pump is to be left in place for more than one month then connections should be hard piped. Flexible hoses used for flushing purposes must be sterilised before use to avoid the risk of bacterial contamination.

2. All flexible hose connections should be screwed. Quick release couplings or jubilee clips could present a hazard if they work loose or are released under pressure.

3. A regulating valve with flow measurement device is required on the return connection from the system to permit measurement and regulation of the flushing velocity. For this application, a variable orifice regulating valve offers greater flexibility since it can be used to measure a wider range of flow rates.

4. A strainer on the pump inlet is required to protect the pump against circulating debris.

5. The entire temporary pump set should be mounted in a tank or bund so that drips or spillages do not cause damage to under-floor services, structure or finishes.
6. A water supply will be required to replenish dirty water drained from the system. The smaller the supply available the longer it will take to clean the system. To facilitate the process, flushing connections should be provided in the boosted cold water riser by the base-build team. A double check valve or a break tank with type A air gap will be required to prevent possible back contamination of the boosted supply in compliance with the current Water Regulations.

7. A drain connection will be required to remove dirty water. A purpose-made drain point should be installed in the main foul drainage system at a convenient location for this purpose. An effluent permit will be required and this may need to include all chemicals proposed for use and those present in the system. Where a trapped waste connection is provided solely for the purpose of facilitating the flushing process, this must be removed and capped after completion.

8. A thermometer on the outlet from the pump will provide a check that circulating temperatures are below levels at which bacteria could multiply.

5.3.3 The cleaning process

With the appropriate temporary pumping facilities in place, flushing and chemical cleaning of the new system pipework can be carried out following the same basic procedures as described in Sections 3 and 4 of this guide. On completion of the clean, the system should be immediately dosed with corrosion inhibitor and biocide chemicals as recommended in section 4.2.7. All chemicals used should be compatible with those used in the existing system.

Seven days after completion of the final dosing, samples should be taken in order to check compliance with the criteria set down in section 1.4 (item 7). If the results are not satisfactory, the cleaning process may need to be repeated.

5.3.4 Maintaining system cleanliness

The entire process of flushing, chemical cleaning and dosing the new system should be timed such that connection to the existing system can take place as soon as possible after completion. Since time is needed to prove adequate water quality, this is unlikely to be less than two weeks after completion of the clean.

During this period, the temporary pumps must be used to circulate the clean water and treatment chemicals. The pumps should be run intermittently, at intervals recommended by the water treatment specialist, making sure to avoid any increase in water temperature that might promote bacteria growth. Furthermore, groups of terminals may need to be temporarily isolated in order to force treated water to circulate around more remote branches rather those closest to the pump.
If the system is to be operated in this way for a prolonged period, the water treatment specialist should recommend a sampling regime to check water quality and undertake dosing as required. Where temporary pumps are to be shared between different circuits, care must be taken not to spread bacteria between circuits via the temporary pump.

5.3.5 Final connection

Final connection should be made only when satisfactory water analysis results have been obtained for both existing and newly installed pipework. It is a good idea to implement a certification system to confirm and record system cleanliness prior to connection. An example form is shown in Appendix E.

Care should be taken to ensure that the spool piece is in a clean, treated condition before it is connected into the system. If the spool piece shows signs of internal corrosion or contamination, it should be cleaned using appropriate cleaning chemicals. Before installation, the spool piece should be immersed in inhibitor and biocide chemicals overnight. To facilitate this operation, spool pieces should be kept as small as possible.

Prior to installation the spool piece should be visually inspected and its condition witnessed by the relevant parties.
APPENDIX A - CALCULATION OF MEAN FLUSHING VELOCITIES

The mean velocity required to move a solid particle from rest on a horizontal pipe surface will vary depending on the pipe size and the particle’s shape, density and cohesiveness with the surface. It has been found from experimentation that water flushing is satisfactory for removing steel debris of most shapes and sizes, although long steel rods are more difficult to move than even-shaped particles. An experimentally derived equation for calculating the mean water velocity required for flushing evenly shaped steel particles in pipework systems is as follows:

\[ U = \left\{ 0.255(R)^{0.12} (h)^{0.48} \right\} \pm 25 \text{ percent} \]

where

- \( U \) = flushing water mean velocity (m/s)
- \( R \) = pipe internal radius (mm)
- \( h \) = particle height (mm).

Applying the upper limit of this equation to different pipe and particle sizes, it is possible to derive values for flushing velocities in different worst case situations. Table A1 contains typical flushing velocities estimated using the above equation. The required flushing flow rate must be calculated for the largest pipe size in the system or circuit to be flushed.


**Table A1:** Mean flushing velocities (m/s) for horizontal medium grade steel pipework (BSI 1387 up to 150 mm pipe size, BSEN 10220:2002 150 mm - 600 mm pipe size).

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<th>Particle size (mm)</th>
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APPENDIX B -  PROCEDURE FOR PRE-COMMISSION CLEANING WITH INHIBITED ACID

The following is a general procedure and may require modification to meet the needs of a particular situation. Such modifications should be discussed with the customer and agreed at the planning stage. The use of side stream filtration during the final stages of the process can reduce the amount of solids to be removed by final flushing and greatly reduce the volumes of flushing water required.

1. Install portable pumps, tanks and make all necessary temporary connections. Circulate and prove all the temporary pipework.

2. Inject monoammonium citrate solution to give the required concentration in the system (2-2.5% active material).

3. Circulate the system using the main circulating pumps, operating such valves as are necessary to ensure that all subsidiary or parallel circuits are fully circulated. Check that the cleaning agent is present at all drain points by means of conductivity measurement.

4. Circulate for about 4 hours, then leave for an 8 hours static soak before circulating for a further 4 hours, during which all the valve operations required to enhance circulation in parallel circuits should be repeated.

5. Drain the system as rapidly as possible then refill rapidly with fresh water and inject the recommended concentration of anionic flocculent. Circulate fully for a further 2 hours (minimum) and drain rapidly.

6. Refill the system, establish circulation and commence flushing from each drain point in turn at a rate which can be balanced by the available make-up water supply.

7. Continue flushing from each drain point until conductivity measurements show no evidence of residual cleaning chemical and the levels of suspended solids and dissolved iron are within specification.

8. When the flushing conditions are to the satisfaction of the customer, retain a water sample for reference and dose the system with a proprietary neutralising and passivating agent which will be compatible with the intended final water treatment. Check for the correct concentration at a selection of drain/sample points and adjust as necessary. Circulate the complete system for 24 hours during which time each item of terminal plant previously excluded from the clean should be brought into circulation after reverse flushing the unit to waste until clear.

9. Drain the system as completely as possible, refill with fresh mains, softened or demineralised water as specified and add the required dose of the appropriate water treatment chemicals.

10. Circulate, test the concentration of the water treatment chemicals and adjust if necessary. Retain a sample of final treated system water.
APPENDIX C -  POLYMER CLEANING (WITH SIDE STREAM FILTRATION/SEPARATION)

During the course of the chemical cleaning operation the side stream unit will be used to remove Fe$_3$O$_4$ (magnetite), other ferrous oxides and any other suspended solids. The unit would typically be installed across system flow and return headers using system differential pressure or a small circulating pump to provide water through-flow. It may not be intended that the unit should remove all the suspended solids unless an extended period of chemical circulation could be tolerated within the building programme, or the unit is being used for system refurbishment. In most cases a period of system flushing would be required.

The basic stages of a system through the dosing pot or make up tank clean are as follows:

1. Add to the system through the dosing pot or make up tank the required quantity of polymer cleaning chemical.

2. Circulate the chemical for a period of at least 24 hours in order to produce a homogeneous solution in all parts of the system.

3. Connect and put into circulation the side stream filtration unit. The pressure difference across the unit should be allowed to build up to between 70-100 kPa for efficient suspended solids removal.

4. Take water samples from system extremities and measure the conductivity of the circulating water. The result will indicate the level of cleaning chemical in the water. If polymer/nitrite or polymer/molybdate combinations are used for cleaning then samples can be tested for nitrite or molybdate concentration.

5. Ensure that a minimum figure of nitrite for all parts of the system is achieved. If inconsistent figures are produced the possible cause should be investigated. If the nitrite figures are lower than the minimum, then the system volume is greater than was specified by the designer and additional chemical will be required.

6. Circulate the system for a period of 72 hours, continuously if conditions allow, but for at least 10 hours per working day. During the period of circulation, the sidestream unit should be back-washed to remove entrained debris from the separation bed as frequently as necessary to maintain optimal filtration/separation within the above stated pressure difference limits. Back-washing may be carried out using system water or by using a suitably sized and designed packaged backwash set that is fed by mains water.

7. During the period of chemical circulation, take samples from the system at agreed sample points every 10 hours. The samples should be analysed on site by the chemical cleaning specialist and the results used to determine if a further period of circulation is required. If stability has been reached, then the procedure can pass on to the next phase.
8. Flush the system using fresh mains water to remove all chemicals and colloidal iron from the system.

9. Immediately upon completion of final flushing, dose the system with final system passivation/inhibitor chemicals and biocide. Final sampling results should be within the limits defined in Section 1.4 of the main Guide. The sidestream filtration/separation unit may be left valved into the system to continuously clean the circulating water or to assist in debris removal if the system is drained and becomes re-contaminated at a future date.
APPENDIX D - PROCEDURE FOR PRE-COMMISSION CLEANING WITH FORMULATED PRODUCTS

The precise method for cleaning with a formulated product cleaner will vary, depending on the particular formulation used.

1. Remove general contaminants from the system by undertaking static and dynamic flushing immediately prior to addition of the formulated cleaning agent.

2. Introduce calculated and measured amounts of cleaning agents to the system strictly in proportion to its water content.

3. Circulate the cleaning agent through the entire system using the system pumps. Ensure even distribution by carrying out appropriate tests in accordance with the cleaning specialist’s instructions.

4. Add further quantities of chemical as required, until on-site tests reveal the cleaning process to be complete. The duration of the clean should be in accordance with the cleaning specialist’s recommendations, but will be dependent upon the temperature of operation and chemical concentration achieved.

5. Drain the system and refill immediately. Commence dynamic flushing, checking at each stage that adequate flow rates are being established. These should be recorded.

6. Continue the flushing process until the chemical cleaning agents have been completely removed.

7. Take samples of water for analysis at agreed locations and sufficient in number to be representative of the system as a whole.

8. Where inhibitors, biocides and other treatments have been specified, add these to the system immediately on completion of the cleaning programme.

9. Prepare a technical report on final completion of the works or on completion of stages in the work programme, as deemed necessary.
## APPENDIX E - EXAMPLE CERTIFICATE OF CONFORMITY FOR SYSTEM CLEANLINESS

### CERTIFICATE OF CONFORMITY FOR SYSTEM CLEANLINESS

<table>
<thead>
<tr>
<th>Contract Name:</th>
<th>.................................................................................................................................</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract No:</td>
<td>.................................................................................................................................</td>
</tr>
</tbody>
</table>

Certification of Conformity with cleanliness levels requested for Base Build/Fit-out connection following assurances of bacteriological free systems on both sides.

System: ......................  Floor: ................................. Area: .................................

1. Has certificate of fit-out system cleanliness been produced indicating acceptable water quality and bacteria levels?  
   - Yes  
   - No

2. Has certificate of base building system cleanliness been produced indicating acceptable water quality and bacteria levels?  
   - Yes  
   - No

3. If the answers to 1 and 2 above are “Yes” and the following signatures are in place, connection/turn on can take place.

Signed: ................................. Date: ................................. For: .................................

Signed: ................................. Date: ................................. For: .................................

Signed: ................................. Date: ................................. For: .................................

Comments:
GLOSSARY OF TERMS

**BIOCIDES**: A chemical agent which either kills or prevents the multiplication of biological organisms in water systems.

**CAUSTIC SODA**: Sodium hydroxide that contains 76–78% sodium oxide; the most important of the commercial caustic materials.

**CHELANT (CHELATING AGENT)**: An organic compound causing a substance which would normally be insoluble to be held in solution or to pass into solution.

**DETERGENT**: A synthetic cleansing agent resembling soap in the ability to emulsify oil and hold dirt, and containing surfactants which do not precipitate in hard water.

**DISPERGANTS**: Substances which create a repellant force between individual particles, thereby encouraging them to remain in suspension during flushing.

**FLOCCULANT (FLOCCULATING AGENT)**: High molecular weight polymer which encourages particles to agglomerate. Sometimes used as an aid for cleaning and flushing.

**INHIBITOR**: Also known as restrainer. Any compound that suppresses corrosion, regardless of which electrochemical reaction it affects. The term inhibitor applies to two distinctly different chemicals, commonly in use. Acid inhibitors control the action of an acid solution used for cleaning; corrosion inhibitors control the further corrosion of the pipe surfaces under normal operation.

**MILLSCALE**: A surface layer of ferric oxides mostly Fe₃O₄ formed during the manufacture of mild steel pipes.

**PASSIVATOR**: A compound that renders the “active” surface of the pipework “passive”, i.e., less prone to further corrosion. Every passivator is an inhibitor.

**SEQUESTRANT (SEQUESTERING AGENT)**: A substance that removes a metal ion from a solution by forming a complex ion that does not have the chemical reactions of the ion that is removed. A sequestrant may be a chelating or complexing agent.

**SURFACTANT (SURFACE-ACTIVE AGENT)**: A soluble compound that reduces the surface tension of liquids, or reduces interfacial tension between two liquids or a liquid and a solid. Commonly used during the de-greasing stage of the clean, in conjunction with a de-greasing agent.
BIBLIOGRAPHY


