

Professional Water Well Drilling

Concerns about corrosion and the  
quality of handpump components in  
Burkina Faso and beyond

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*Dr Kerstin Danert*  
*5 November 2019*

This report has been prepared thanks to funding from the 2015-2017 and 2017-2019 Programme Collaboration Agreements (PCA) between UNICEF and Skat Foundation. Additional funding was obtained from Skat Consulting Ltd. Projektfonds, which has supported the author to lead the Rural Water Supply Network (RWSN) Sustainable Groundwater Development theme since 2008.

#### **How to cite**

Danert, K (2019) **Concerns about the quality of handpump components in Burkina Faso and beyond**, Skat Foundation, St Gallen, Switzerland

#### **Frontispiece**

Corroded rising mains being photographed as part of a physical audit of water facilities in Burkina Faso

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## Abbreviations

Ø	Diameter
ANSI	American Iron and Steel Institute
BIS	Bureau of Indian Standards
EMPA	Swiss Federal Laboratories for Materials Science and Technology
ERW	Electric Resistance Welded
GI	Galvanised Iron
IS	Indian Standard
ISO	International Standards Organisation
KfW	Bank for Reconstruction ( <i>Kreditanstalt für Wiederaufbau</i> )
NB	Nominal Bore
ND	Nominal Diameter
SS	Stainless Steel
UPVC	Unplasticized Poly Vinyl Chloride

## Summary

In Burkina Faso, concerns have been raised regarding the high number of handpump boreholes that have failed, or need to be rehabilitated within a relatively short time of their initial construction. Physical audits of handpump boreholes in 2013 and 2014 in Burkina Faso raise concerns over water quality, inappropriate handpump for deep water and non-conformant pumps. In more than one third of cases, the handpump boreholes will function poorly, or cease to function completely within a few years. It is estimated that investments of between FCFA 0.6 billion (€0.9 million) and FCFA 2.9 billion (€4.5 million) per year are lost due to the installation of poor quality handpumps and other aspects of the construction. In one year, over 130,000 people were provided a water supply service that is likely to break down within a few years.

Despite knowledge of handpump corrosion for over 30 years, it remains a problem in Burkina Faso, as governments and aid agencies have continued to install pumps manufactured with unsuitable materials, leading to high maintenance costs, pump failure and rejection of water sources due to poor water quality. Handpump corrosion is a major global problem which the WASH sector has so far, systemically failed to address, and which will impede the realisation of Sustainable Development Goal 6, not only in Burkina Faso. Concerns cited by experts from a range of countries on the Rural Water Supply Network (RWSN) online discussion platforms include the following: inadequate quality of materials and components, lack of quality control, unrealistic (low) prices and problematic purchasing practices.

A renewed call to investigate the quality of handpump components in Burkina Faso was raised with Skat Foundation by the Government and UNICEF Burkina Faso in early 2017. Samples of the rising main and pump rod were purchased from three suppliers in Ouagadougou during the Skat Foundation 2017 mission. An additional seven samples were taken in 2019 from pumps that were in use or had been abandoned. All samples were tested for their chemical composition in 2019. Analysis showed that: five of six sampled riser pipes, and two of four sampled pump rods do not conform to international standards for the composition of stainless steel of the specified grade. In particular, the low nickel content of these samples means that the components have less corrosion resistance than they would if they were of the specified grade.

Both Skat/Rural Water Supply Network (RWSN) and the Bureau of Indian Standards have published standards for the India Mark II and III handpumps. In addition, information on what can, or should be ordered is available from manufacturers through their brochures and websites. UNICEF has product details of various India Mark II and III models in their Supply Catalogue, and UNICEF offices set out specifications in their purchase orders. Notably, these different publications are not always consistent, and there are gaps.

The small sample size of 13 components tested in this study is not a statistically representative of the situation in Burkina Faso as a whole. However, it verifies the concerns raised by the Government that something is not right with some so-called stainless steel components available on the market but the extent of the problem remains unknown. However, it is also very important to note that it is possible to purchase stainless steel riser pipes, pump rods and welded sockets according to specifications, as evidenced by the fact that six of the thirteen samples did conform to international standards.

This short study has shed light on a number of interconnected issues for Burkina Faso and beyond:

1. Further research on the use of stainless steel components to prevent the corrosion of below ground handpump components that are installed in aggressive groundwater is needed.
2. There appear to be some errors in the Indian Standard for India Mark II and III, and options for aggressive groundwater are not addressed. The international standards (including those published by Skat/Rural Water Supply Network) regarding the handpump component materials for aggressive groundwater could be improved.

3. There are numerous companies in India selling India Mark II and III handpumps and components. Some of the sales prices are so low, that adhering to international standards does not seem feasible.
4. There is no international body systematically controlling handpump material quality, and the role, as well as activity of the Bureau of International Standards in this regard is not clear or apparent.
5. When the purchase of handpumps is undertaken within the country of installation the long (and anonymous) supply chain, provides little or no connection between manufacture (primarily in India) and installation of the pump. In addition, a lack of systematic documentation of problems experienced means that the agencies, companies or households installing handpumps are not aware of the extent, and scale of quality problems until it is too late.
6. Many of the handpumps used in Africa are imported from India (and apparently Nigeria too), and so efforts to address the problem of quality assurance need to include several African countries as well as India.
7. Donor interest in handpump hardware is arguably at its lowest in 30 years, and so galvanising interest to develop an international certification process or fund research is extremely difficult. Such an initiative would require not only investment, but also long-term commitment from the large agencies and governments that fund and implement programmes installing handpumps and their maintenance.

Consistently assuring the quality of the India II and III, and Afridev handpumps is not just a challenge for Burkina Faso but more widely. Concerns have also been raised regarding some Afridev components in another country, but the extent of the problem is not known. The India Mark II and III, as well as the Afridev are the choice of pump in many countries, with spare parts supply chains often well established. What is being witnessed, as documented in this report, is essentially a failure of "the market" to consistently deliver high quality materials. Addressing this failure requires solutions from within importing countries, such as Burkina Faso, but also internationally.

It is hoped that this short study will trigger interest by governments, and by research organisations, and international development agencies to explore ways to solve the problems of corrosion and poor quality handpump components. If this is not done, by inadvertent neglect, the global water supply community is arguably preventing rural populations in Burkina Faso and beyond from the benefits of a reliable, basic drinking water supply.

# 1 Introduction

In Burkina Faso, concerns have been raised regarding the high number of handpump boreholes that have failed, or need to be rehabilitated within a relatively short time of their initial construction. Physical audits of handpump boreholes in 2013 and 2014 in Burkina Faso raise concerns over water quality, inappropriate handpump for deep water and non-conformant pumps. In more than one third of cases, the handpump boreholes will function poorly, or cease to function completely within a few years. Danert *et al* (2019) estimate that investments of between FCFA 0.6 billion (€0.9 million) and FCFA 2.9 billion (€4.5 million) per year are lost due to the installation of poor quality handpumps and other aspects of the construction. In one year, over 130,000 people were provided a water supply service that is likely to break down within a few years.

Despite knowledge of handpump corrosion in Burkina Faso for over 30 years, the problem remains, as governments, aid agencies and possibly others have continued to install pumps manufactured with unsuitable materials, leading to high maintenance costs, pump failure and rejection of water sources due to poor water quality. Handpump corrosion is a major global problem which the WASH sector has so far, systemically failed to address, and which will impede the realisation of Sustainable Development Goal 6, not only in Burkina Faso.

The renewed need to investigate the quality of handpump components were raised with Skat Foundation by the Government and UNICEF Burkina Faso immediately prior to the author's field assignment in February 2017. The aim of the assignment was to support efforts to raise professionalism with respect to borehole drilling in the country (Danert *et al*, 2019). Unfortunately, given the broad scope of the planned assignment, it was not possible to consider the issue of handpump components in detail. However, supported by the Burkina Faso drillers association, samples of the rising main and pump rod were purchased from three suppliers in Ouagadougou during the 2017 mission and sent to Switzerland with view to testing the material composition.

Due to a gap in funding, the tests had to be postponed and took place in early 2019, thanks to a new collaboration between UNICEF and Skat Foundation. The first set of tests were followed by the testing of additional samples taken from pumps that were in use or had been abandoned. Analysis of the chemical composition of 13 samples showed that: five of six sampled riser pipes, and two of four sampled pump rods do not conform to international standards for the composition of stainless steel of the specified grade. Discussions on the Rural Water Supply Network (RWSN) online forum on Sustainable Groundwater Development revealed concerns, and provide examples of poor material quality from other countries. As mentioned above, this problem is not confined to Burkina Faso alone.

This report is structured as follows:

- chapter 2 provides background to the India Mark II and III pumps;
- chapter 3 gives a synopsis of iron and corrosion issues;
- chapter 4 summarises concerns that have been raised about handpump components;
- chapter 5 provides an overview of the specifications, standards, brochures and catalogues that can be used to specify the purchase of the India Mark II and III pumps
- chapter 6 presents the test results from Burkina Faso
- chapter 7 concludes the report

## 2 India Mark II and III Pumps

Millions of households around the world, and in rural Africa in particular, use the India Mark II or III handpump (Figure 1) to lift groundwater and thus provide drinking water supplies (Bauman and Furey, 2013). The India Mark II (and India Mark III, which was developed from it), is the handpump of choice by governments and

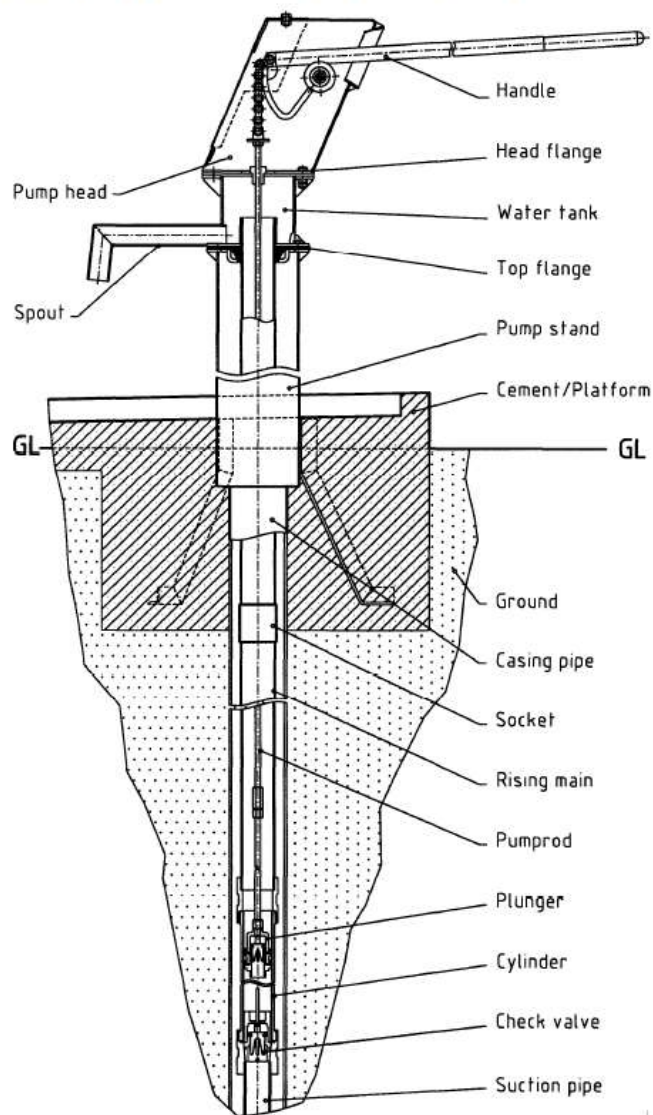
development agencies in many countries (MacArthur, 2015). The pump is a community pumps, designed to serve user groups of 200 to 500 people. It was developed and tested in India in the late 1970's as a United Nations Development Program (UNDP)/World Bank/UNICEF and Indian private sector collaboration entitled "The Handpump Project".

The Rural Water Supply Network (RWSN)<sup>1</sup> has published international specifications that are freely available to any manufacturer who wishes to produce the India Mark II handpump (Skat/RWSN, 2007). The Bureau of Indian Standards (BIS) also issued standards (Annex 2). Given that most of the India Mark II components that are available on the international market are manufactured in India, the Indian standards are particularly important.

The pumps are robust and, if manufactured and assembled according to the standards, properly maintained with fast-wearing parts replaced regularly, should last 20 years. Concerns have been raised about handpump components being installed that do not meet the RWSN and BIS standards as a significant cause of premature breakdown (Bonsor et al, 2015; Casey et al, 2016; Furey, 2014).

Handpump corrosion is widespread in many countries, resulting in the rejection of the water supply by the users to its taste and colour or due to the premature failure of components and the abandonment of the supply or costly rehabilitation.

**Drawing of an India Mark III Pump installed on a Borehole**



**Figure 1 Drawing of an India Mark III pump installed in a borehole**

<sup>1</sup> Formerly the known as the Handpump Technology Network (HTN), with secretariat hosted by Skat in St. Gallen, Switzerland.



### 3 Iron and corrosion

High iron content of the water pumped from India Mark II and III has been documented to occur in some areas of several countries. This iron can be naturally occurring, or due to corrosion of handpump components, or both:

- Natural occurring iron - iron is present in soils and rock formations in either its reduced soluble form ( $\text{Fe}^{+2}$ ) or as oxidized insoluble ferric iron ( $\text{Fe}^{3+}$ ). The nature of the soluble, colourless form is such that it can be in the groundwater but appear colourless, yet when pumped out of the ground, and exposed to the atmosphere, will convert to ferric iron, which subsequently reacts to form insoluble iron hydroxides. As these precipitate out, a red/brown cloudiness is observable in the water, which stains.
- Pumped groundwater can also contain high iron concentrations due to corrosion of pump components in aggressive groundwater. Corrosion is a complex problem, depending on a number of factors and there is no universal index for predicting corrosion in all water quality conditions (Annex 1). What is clear is that galvanisation does not protect the riser pipe (also referred to as the rising main) if the pH is less than 6.5 and galvanisation only provides limited protection for pH of 6.5-7 (Langenegger, 1994). Pump rods made of stainless steel have corrosion rates an order of magnitude lower than galvanised iron (Langenegger, 1994).

There are cases in which both naturally occurring iron and corrosion occur, but simple tests have been developed to help distinguish the source (Casey et al, 2016).

Attempts to prevent handpump corrosion include the standardisation of pumps to those that are fully corrosion-resistant e.g.

- Afridev in Mozambique, Nigeria, Tanzania and Ethiopia (Bauman and Furey, 2013)
- Afridev and a modified version of the India Mark II with stainless steel components in Ghana (MacArthur, 2015)
- Stainless steel components by some donor-funded programmes in Zambia (MacArthur, 2015)
- Corrosion problems of the India Mark II and III (known in Uganda as the U2 and U3) in Western Uganda, resulted in the development of a corrosion-resistant U3M pump. Further, in 2016 a directive from the Ministry of Water and Environment was issued stating that use of galvanised iron components must stop (Liddle and Fenner, 2018).
- Use of stainless steel risers by World Hope in Sierra Leone (Furey, 2014)
- Replacing galvanised pipes with PVC pipes and stainless steel pump rods in southern Senegal in the USAID/PEPAM project (Furey, 2014)
- Ensure that there is not a mix of stainless steel and brass, as the presence of brass will cause the stainless steel to corrode (Van Beers, 2018)

Despite the above, corrosion problems continues to be widespread, and unfortunately have not been systematically documented. Furey (2014) reported problems with corrosion and/or high iron in 13 countries in sub-Saharan Africa, as well as Bolivia and India. Danert et al (2017) report on corrosion problems in Burkina Faso.

Research in Uganda showed that switching to corrosion-resistant materials is not simple. In the Ugandan case, the supply-chain for corrosion-resistance materials was found to be weak with uncertainties about quality, little demand, low levels of stock and in general, a continued market dominance of galvanised rods and riser pipes (Liddle and Fenner, 2018). It is still early days to determine the success of the 2016 Ugandan directive but recent research indicates that not all agencies are adhering to using the directed riser pipes, apparently

due to the high cost of stainless steel, with components 4-5 times more expensive than galvanised iron (Liddle and Fenner, 2018).

Furey (2014) also notes that care needs to be taken with the grade of stainless steel because of the electrical potential where there are two different types of metal in contact. It is claimed (by contributor to Furey, 2014) that stainless steel 304 will rust in the presence of stainless steel 316.

## 4 Concerns about Handpump Components

### 4.1 Burkina Faso

Six types of handpump are used in Burkina Faso (India Mark II, India Mark III, Vergnet, Diacfa, Volanta and Kardia), but according to stakeholders, the current preference is for the India II and Vergnet brands). The problem of handpump corrosion is widespread. Although some organisations claim to use stainless steel riser pipes rather than galvanised iron for the India II, the government has raised concerns about the quality of the stainless steel, and whether it may also be subject to corrosion. Physical audits of facilities undertaken in 2013 and 2014 indicate major corrosion problems (Danert *et al*, 2017).

In February/March 2017 Skat Foundation was contracted by UNICEF to undertake a short study of the drilling sector in Burkina Faso. The study found several interrelated factors in the country undermine the quality of the completed borehole, including the capacity of the public sector to supervise drilling; outdated reference prices; a very short drilling season due to timings of procurement, the issue of contract, and onset of the rainy season and poor quality handpump components.

UNICEF Burkina Faso used to import handpumps directly from certified factories in India but this is no longer the case. Today, there are several suppliers in Ouagadougou that import from India (and possibly elsewhere) selling handpump components to drilling companies which install them under contract to Government, NGOs and UNICEF and possibly also for private clients.

The India Mark II is not protected by a production license and there are all levels of quality on the market. There are many concerns about cheap pumps and counterfeit pump components. The government has begun to take steps to address this problem but is asking for advice on how best to ensure the quality of stainless steel pump rods and risers. Danert *et al* (2017) recommended that the country develop quality assurance mechanisms for India II components, which are linked to a permit or licence for the supplier. However, as a preliminary step, and to gain some insights into what is actually available on the market in Burkina Faso, a small sample of handpump components were sent to Switzerland for materials testing. The test procedures and results are presented in Chapter 6.

### 4.2 Other Countries

Concerns about the use of poor quality materials (particularly stainless steel and galvanised iron riser pipes and pump rods) are not just confined to Burkina Faso. Alas, with few exceptions (e.g. Box 1) there are scant reports or academic publications on the quality of handpump components. Several members of the Rural Water Supply Network (RWSN) wrote and spoke to the author over the few years, either in response to questions posed by the author on RWSN's online group - Sustainable Groundwater Development<sup>2</sup>, or as a reaction to other posts. Four main themes of concern emerge, i.e. quality of materials and components; quality control; unrealistic prices; and purchasing practices. Where the reference is (Anon, nd), the respective

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<sup>2</sup> [https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)

statement was provided anonymously by experts in the sector, but cannot be substantiated. However, these experiences have been considered by the author as important to build understanding on this otherwise poorly documented subject.

### Box 1 Concerns about the quality of stainless steel pump rod and riser pipe components in Uganda

Liddle and Fenner (2018) report that stakeholders in **Uganda** informed them that lower grade stainless steel, which corrodes, is being imported and installed, and that there is currently no regulation of the quality of the materials imported by the Uganda Bureau of Standards: *"It [stainless steel] has to be imported, we import ours from India. We import 304 or 305 grade. There is a big issue here though, many are importing from China and the quality is terrible, only 202 grade. But we have no mechanism in Uganda for checking the grade as it arrives in the country so we end up with terrible stainless steel being used"* (Drilling contractor).

### Quality of materials and components

- **"Scrap" material is being sold as Stainless Steel** 202 as well as 304, 304L and 316 (Box A5.1):
  - Clients do not know the difference (Anon, nd).
  - Notably, the quality of Stainless Steel is not a new problem. It was faced in the Danida Programme in Coastal Orissa (1986-92), which moved from 304 to 316. (Anon, nd)
  - *"There has been much criticism of NGOs installing poor quality galvanized pump components in corrosive water, but when you upgrade to much more expensive [stainless steel], there are still problems... we started buying pump sets with Stainless Steel connecting rods from a local supplier...[but later received] many reports of the pumps breaking down in the first few months. We inspected them and found that the eyes on the connecting rods were cracking and breaking. We contacted the manufacturer in India and were told that the supplier we purchased from buys low quality [stainless steel] made from scrap metal. We asked the supplier about this and were told that no one will pay for the high quality so he does not stock it. We made a minimum purchase agreement with the supplier so he would import the good quality for us. The quality is now very good with threaded joints instead of the hook & eye. We looked at the [stainless steel] rods sold at other suppliers and found it was a very thin plating of stainless steel with it sometimes chipping off at the ends."* (Norris, 2019)
- **Handpump riser pipe materials of variable quality** on the market in some African countries, include galvanised iron (GI) riser pipe:
  - There are concerns about the quality of the galvanising, of the riser pipe, and other components (Anon)
  - Wear of threading of the rods after three months of installation in Niger (Abdou, 2018)
  - Visual inspection of the corrosion by an industry expert indicates that there is little or no pre-treatment ahead of the hot dip galvanising<sup>3</sup> (Anon, nd).
  - Non-compliant galvanising processes (Anon, nd).
  - GI riser pipes with a thinner wall thickness than specified (Anon, nd).
  - *"Brand AOV IM2 hand pumps purchase by a Chinese drilling contractor in Zambia from India. The steel plate was thinner as were the GI pipes, the overall weight was far lower than one built to [Skat Specifications]. The 3<sup>rd</sup> plate was missing. The rods were electroplated mild steel. 100's of these were installed all over Zambia under a contract with Client Y. I investigated this case*

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<sup>3</sup> Pre-treatment guidelines for galvanising: <http://www.galvanizing.org.uk/learn-more/the-process/>

*and at the end of the day was not even sure if the pumps came from AOV or somewhere else. Certainly their name plate was on the pedestal" (Anscombe, 2019b).*

- **Poor quality components:**
  - Sale of narrower diameter connecting rods (11.2 to 11.6 mm Ø rather than 12 mm Ø) with the result that and male and female threads do not connect properly leading to premature failure (Anon, nd). Use of substandard and smaller diameter bright bar (i.e. 12.5 mm instead of required 14 mm) resulting in the bending of rods as the material remains soft (Anon, nd).
  - Head assembly materials not of the correct sectional thickness so that what should have a weight of 25kg in practice only weighs 20kg. The thinner materials will result in a lower-strength component and reduce the strength of the welds (Anon, nd).
  - Use of lower quality roller bearings and reduction in bearing housing sectional size (Anon, nd).
  - Chemical composition of the cylinder sleeve include higher lead, which makes it softer (Anon, nd).
- **Afridev problems** include:
  - *"The AFRIDEV revision 3 plunger and footvalve are made of plastic. Ram Trivedi of UNICEF India came to visit and we checked some in a local store in Malawi. He showed us the corner of a blue shopping bag in one footvalve sample! – stating that it was common for these to be manufactured from second hand plastic in Delhi ... after which cheapest-wins-the-contract policy sees them flooding Africa" (Anscombe, 2019b)..*
  - *".. problem with the cast iron hook on the Afridev Rev 3 which when cooled too quickly would leave a flaw in the casting causing it to snap and for the users to then have to find and purchase a new one" (Anscombe, 2019b).*
  - Quality problems are not just confined to the India Mark II and Mark III but also concern the Afridev pump (Anon, nd)

### **Inadequate quality control**

- Insufficient qualified and trained engineers in the pump manufacturing industry to control quality properly (Anon, nd).
- Lack control of the quality of exports (from India), particularly of what is actually loaded onto the container (Anon, nd).

### **Unrealistic (low) prices**

- Concerns have been raised about unrealistically low prices, forcing manufacturers who would otherwise produce material of good quality to lower standards and thus remain in the market (Anon, nd).
- Buyers and agents dictating unrealistically low prices to the manufacturers for which the specifications cannot be realised (Anon, nd).

### **Problematic purchasing practices**

- Clients knowingly ordering sub-standard materials, which are either installed, or sold on, for a profit (Anon, nd).
- *"In the Zambia [North Western] Province project the hand pump contract was under the Ministry of Local Government and Housing with us the consultant organising it and KfW paying once everyone had agreed. There was a public tender stage with the best evaluated awarded – with the Consultant leading the evaluation... for IM2 with fully stainless steel riser pipes and pump cylinders... expensive pumps but they are still functional 8 years later which to me means they were cost effective (Anscombe, 2018)*

- *"Big Govt drilling programs are often awarded to the cheapest tenderers and with this comes the inevitability that the hand pumps are lower priced and lower quality than desired. India is full of sweat shops making hand pump parts. For export there are firms which put together hand pumps from a variety of sources ...these are Suppliers. Then there are the Manufacturers who make all the components under one roof, assemble and check the operation of the handpump before export. The latter hand pump may be \$20 more expensive than the former but cost effective in the longer term"* (Anscombe, 2019a)

## 5 Specifications, Standards, Brochures and Catalogues

Both Skat/Rural Water Supply Network (RWSN) and the Bureau of Indian Standards have published standards for the India Mark II and III handpumps, In addition, information on what can, or should be ordered is available from manufacturers through their brochures and websites. UNICEF has product details of various India Mark II and III models in their Supply Catalogue, and UNICEF offices set out specifications in their purchase orders. Notably, these different publications are not always consistent, and there are gaps. This chapter provides an overview of these five different information sources. Unfortunately, a comprehensive analysis of all the gaps and inconsistencies was beyond the scope of this assignment. However, it is hoped that this chapter can provide a good basis for others to take up this subject in more detail in the future.

### 5.1 RWSN Specifications

The most recent RWSN India Mark specifications were released in 2007. They include:

- Pump rod – options:
  - mild steel or
  - stainless steel

The pump rod specifications note that stainless steel rods should be used in water with pH<6.5, but this advice is not very prominent and thus easy to overlook.

- Riser pipe and couplings
  - galvanised iron only

There are no stainless steel or uPVC options.

- Cylinder assembly
  - India MK II - cast iron (GG20) cylinder and brass liner
  - India MK III - cast iron (GG20) cylinder and brass liner

There are no stainless steel or brass options.

For further details, see Annex 3.

### 5.2 Indian Standards

IS 15500:2004 – *Deepwell Handpumps, Components and Special Tools Specifications* covers the following Handpumps, including components and tools for:

- STANDARD (SDWP)
- VLOM 65
- VLOM 50
- EXTRA DEEP
- FORCE LIFT

Table 1 provides an overview of the handpump types (above) with the casing diameter and static water range, but it does not explain that the VLOM-65 and the VLOM-50 refer to the India III pump.

The standards only include galvanised iron riser main (no mention of stainless steel or uPVC options).

There are three material specifications for the connecting rod, i.e. two different grades of stainless steel and mild steel (electro-galvanised) but no clear mention of options. It is not clear whether the two grades of stainless steel are different options, or whether they are a typographical error, as they appear in different sections of the document. The dimension drawings of the connecting rod only mention electro-galvanised materials although stainless steel is referred to in Part 1 of the standard.

Section 8 includes a cross-reference to section 6.4 (which does not exist)

There was a process of revision of this standard, with the last date for the receipt of comment as the 30<sup>th</sup> September 2018. Despite attempts by the author in 2018, it has not been possible make contact with the committee responsible for these changes.

### 5.3 Manufacturers Brochures and Website

The study reviewed the websites of three well-known Indian handpump manufactures (Apex, AOV and Meera & Ceiko) to see what options they offer for the connecting rods, riser pipes and cylinder of the India Mark II and how these are communicated to the public<sup>4</sup>. Handpump components are also being manufactured in Nigeria, this is beyond the scope of this short report.

Apex International provides the most comprehensive offer, providing an extremely clear brochure, which also notes the options that need to be considered for “*aggressive waters*”, although it fails to define this in terms of pH. AOV provides “other options” for riser pipes and connecting rods and the cylinder but the corrosion is not mentioned. Meera and Ceiko only give the GI option for riser pipes. The connecting rods are noted as being electro-galvanised against corrosion, with stainless steel option mentioned. Only the cast iron cylinder is mentioned. Box 3 provides further details.

The website Indiamart (2018) provides a portal on dozens of handpump manufacturers throughout in India, and suggests that an India Mark II can be purchased for as little as RPN 3,000 (US\$ 43)<sup>5</sup>. Unrealistically low prices, coupled with the proliferation of handpump suppliers raise questions about whether there is adherence to specifications and quality standards, and how they can be monitored for compliance. With so many companies competing for business and no internationally accredited certification process, it is extremely difficult for clients to know which enterprise is reputable (and continues to be reputable). Unrealistically low prices may also have a knock-on effect on the quality of products by companies trying to maintain standards, but struggling to compete with other putting inferior goods onto the market. Alas, it is the water user (i.e. rural community members) that pay the price in terms of poor, or non-performing handpumps.

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<sup>4</sup> SOVEMA (a leading French manufacturer, particularly into Frabcoophone Africa) could not be reviewed as the website (<https://www.sovema.fr/>) was down for maintenance.

<sup>5</sup> Note that this is the price stated on the website, and not through an official quotation.

**Box 2 Details of information of India II riser pipe, connecting rod and cylinder assembly on websites of three Indian manufacturers of the India Mark II handpump**

Apex International provides a downloadable brochure in pdf format (Apex International, n-d). It provides three options the riser pipe and cylinder assembly and two connecting rod options (Table below). The brochure (pp5) provides a short section on the options "to handle corrosive waters", i.e. brass or stainless steel cylinder assembly with flush end caps; stainless steel connective rods and stainless steel or UPVC riser pipes.

Table **India Mark-II Deep Well Handpump Options (Apex International, n-d)**

Riser Pipe	Cylinder Assembly	Connecting Rod
Option I	GI	Cast Iron Brass Sleeved
Option II	Stainless Steel	Stainless Steel
Option III	uPVC	Brass

The AOL (2018) India Mark II "Salient Features" data, states:

- "riser pipes are comprised of locally available 32 mm NB GI pipes. Other options such as upvc, HDPE & FGP are also available"
- "Connecting rods are of cold drawn bright steel bar with threaded and couplers and are electro-galvanised against corrosion. Alternatively stainless steel rods or FGP rods are also available for better performance".
- "The cylinder is made from a cast iron casing with a polished brass liner and gun metal plunger and check valve components. Seals (pump buckets, valve seals and cap seals) are available in environmentally safe nitrile rubber. Other options include stainless steel, brass and uPVC. The cylinder is adaptable for use with Universal Cylinder components".

Meera and Ceico (2018) India Mark II Deep Well Hand Pump "Features" include:

- "Riser pipes comprise of locally available standard 32 mm NB GI pipes".
- "Connecting Rods are of cold drawn bright steel bar with threaded end couplers, electro-galvanised against corrosion. Stainless steel rods are also available".
- "The Cylinder is made from a cast iron casing with a polished brass liner and gun metal plunger and check valve components".

### 5.4 Product Details from the UNICEF Supply Catalogue

The UNICEF Supply Catalogue includes a range of India Mark II and III handpump options, with various riser pipe and rod configurations including GI, stainless steel and uPVC. According to Harvey (2018) "the uPVC option with SS couplings is the most common option we have seen in recent years (e.g. for Nigeria, which still places the most orders)."

Annex 4 provides further details of four "product details" which cover a range of options not included in the RWSN or Indian Standards i.e.:

- riser pipe
  - upvc with threaded upvc coupling
  - upvc with threaded stainless steel (ss) coupling
  - all stainless steel with welded ss socket
- pump rod
  - stainless steel



Product Description S0009335 refers to IS:15500-2004 with respect to the uPVC threaded coupler although there is no specific mention of uPVC threaded coupler in the standard. Reference to may be with respect to the dimensions of the sockets (pipe sockets) but this is not clear.

Cylinder assemblies were not covered by this short study.

## 5.5 Specifications in UNICEF Purchase Order

One example of a UNICEF country office purchase order requesting uPVC brass lined cylinders, uPVC riser pipe according to IS 15500-2004 (even though these two components are not included in the standard) has been shared with the author. It is not clear whether this is common practice.

## 6 Quality of Materials Sourced in Burkina Faso

### 6.1 Sampling and Testing Process

In order to gain some insights into what is actually available on the market in Burkina Faso, one stainless steel riser pipe and one pump rod for the India II pump were purchased from three different suppliers in Ouagadougou in February 2017<sup>6</sup>. In April 2019, additional samples were taken from five pumps that were in use, or had been abandoned. These were also shipped to Switzerland for testing. Table 1 provides an overview of the samples tested.

Samples 1 to 6 were analysed to determine the elemental composition of each sample. In line with the Bureau of Indian Standards IS 15500 (BIN, 2004), the stainless steel plunger rod material should conform to X04Cr19Ni9 or X04CR18Ni10 (Table A1.1). Samples 7 to 13 underwent a quantitative measurement of the element composition of each material with reference to material 304/304L (material number 1.4301 with the designation X5CrNi18-10) as well as a qualitative detection of lead<sup>7</sup> (Empa, 2019b). For insights into grades of stainless steel, see Annex 5

### 6.2 Test Results and Assessment

Of the six riser pipes sampled, only one was complaint with the international standard for Stainless Steel SS304/304L. Two pump rods, and the three welded sockets tested were also compliant. The low nickel content of the five non-compliant riser pipes means that they are less corrosion resistant than they should be. It should also be noted that in the pumps sampled from the field, materials of different chemical composition are joined can trigger electrochemical processes, also resulting in corrosion. Traces of lead were found in two out of three of the riser pipes, and two out of three of the welded sockets tested but the concentration can be considered harmless in terms of human and environmental toxicology.

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<sup>6</sup> Three sections of 20cm in length were cut from each end and the centre of all six specimens and the resulting 18 parts were taken to Switzerland for measurement and test in order to determine if they meet the Burkinabe pump specifications.

<sup>7</sup> Wavelength-dispersive X-ray fluorescence spectroscopy (WDXRF) is a surface method for determining chemical elements in the range from fluorine to uranium. The sample is excited using X-rays, which are generated by a rhodium tube. The emitted fluorescence radiation is aligned by a collimator, diffracted in an analysing crystal and registered by a suitable detector. The crystal separates the spectrum of the polychromatic secondary radiation emitted by the sample into different wavelengths by diffraction, allowing a qualitative determination of the element based on the diffraction angle of the X-rays and a quantitative measurement by measuring the intensity of the X-ray radiation. The measurement was carried out directly on the cut-out piece using a Rigaku Primus IV device. The measurement range of the elements was from fluorine to uranium (Empa, 2019b).



**Table 1 Overview of Pump Component Samples Tested and Compliance with Standards**

No.	Type of Component	Photo	Origin	Compliance
1	Riser Pipe		Ouagadougou Supplier 1	YES
2	Riser Pipe		Ouagadougou Supplier 2	NO
3	Riser Pipe		Ouagadougou Supplier 3	NO
4	Pump Rod		Ouagadougou Supplier 1	YES
5	Pump Rod		Ouagadougou Supplier 2	NO
6	Pump Rod		Ouagadougou Supplier 3	NO
8	Pump Rod		Volanta pump from Ouakoye, quartier Madina	YES
7	Riser Pipe		India Mark II pump from Sokogo Village	NO
9	Riser Pipe		India Mark II pump from Ouakoye, quartier Abatoir	NO
10	Riser Pipe		India Mark II pump from Darao	NO
11	Welded socket		India Mark II pump from Ouakoye, quartier Abatoir	YES
12	Welded socket		India Mark II pump from Ouakoye, quartier Abatoir	YES
13	Welded socket		India Mark II Pump from Sokogo Village	YES

For samples 1 to 6, the tests were carried out according to the Empa Process SOP 3828. In a modification to the SOP, for samples 2, 3, 5 and 6, the elements manganese, nickel and copper were adjusted to mass concentration for the calibrations. All analyses were carried out by means of three independent determinations (n=3) (Empa, 2019a). For samples 7 to 13, the quantitative measurement of the required material elements was carried out according to the Empa Process SOP 3803. In a modification to the SOP, for samples 7, 9 and 10, the elements manganese, nickel and copper were adjusted with regard to mass concentration for the calibrations. The analyses were carried out by means of 2 independent measurements (n=2) (Empa, 2019b).

The full chemical analysis is provided in Annex 6. Further details as presented in the Empa reports are as follows:

- Within the analytical accuracy of the method, the samples designated 1 and 4 correspond to the materials designated X04Cr19Ni9 or X04Cr18Ni10. They are comparable in their chemical composition. The samples designated 2, 3, 5 and 6 cannot be assigned an official material designation. They are comparable in their chemical composition. Due to the low mass portion of nickel, they are less resistant to corrosion than samples 1 and 4 (Empa, 2019a).
- In the samples designated 7, 10, 11 and 13, traces of lead (Pb) were detected in the region of a few hundred µg/g (ppm). This concentration can be considered harmless in terms of human and environmental toxicology (Empa, 2019b).
- The samples designated as pipes Nos. 7, 9 and 10 do not meet the expected specifications of the material with the designation SS 304 / 304L, material number 1.4301, X5CrNi18-10. They are similar to each other in their chemical composition. The samples cannot be assigned an official material designation (Empa, 2019b).
- The samples designated as pipe sockets Nos. 11, 12 and 13 correspond to the expected material with the designation SS 304 / 304L, material number 1.4301, and the designation X5CrNi18-10 (Empa, 2019b).
- The sample designated as pump rod No. 8 corresponds to the material with the abbreviated name STS303Cu (Republic of Korea) (Empa, 2019b).
- When selecting different materials, it is important to ensure that, if they form joint contact surfaces, no electrochemical processes will be triggered (Empa, 2019b).

## 7 Conclusions

The small sample size of 13 components tested in this study is not a statistically representative of the situation in Burkina Faso as a whole. However, it verifies the concerns raised by the Government that something is not right with some so-called stainless steel components available on the market but the extent of the problem remains unknown. Some riser pipes and pump rods sold as stainless steel and subsequently installed do not have the correct material composition, and are thus not as corrosion resistant as they should be. In addition, it has been documented that different metals are being joined (i.e. riser pipe and welded socket), which can trigger electrochemical corrosion. However, it is also very important to note that it is possible to purchase stainless steel riser pipes, pump rods and welded sockets according to specifications, as evidenced by the fact that six of the thirteen samples did conform to international standards.

This short study has shed light on a number of interconnected issues for Burkina Faso and beyond:

1. Extensive literature on the performance of stainless steel components to prevent the corrosion of below ground parts installed in corrosive groundwater is lacking. Further research in this regard is much needed.
2. Review of IS 15500 indicates that there may be some errors in the standard in relation to material specifications and cross-referencing. Options for India II and III in aggressive groundwater are not addressed by the Indian Standards. The international standards (RWSN and BIN) regarding the handpump component materials that are to be used in aggressive groundwater could be improved to enable organisations that are purchasing handpumps to clearly specify their requirements. As illustrated by the UNICEF supply catalogue, purchase orders draws on several standards, and so ensuring that suppliers adhere to specifications is made difficult.

3. There are numerous companies in India selling India Mark II and III handpumps and components. Some of the sales prices are so low, that adhering to international standards does not seem feasible.
4. There is no international body systematically controlling handpump material quality, and the role, as well as activity of the Bureau of International Standards in this regard is not clear or apparent.
5. When the purchase of handpumps is undertaken within the country of installation the long (and anonymous) supply chain, provides little or no connection between manufacture (primarily in India) and installation of the pump. In addition, a lack of systematic documentation of problems experienced means that the agencies, companies or households installing handpumps are not aware of the extent, and scale of quality problems until it is too late.
6. Many of the handpumps used in Africa are imported from India (and apparently Nigeria too), and so efforts to address the problem of quality assurance need to include several African countries as well as India.
7. Donor interest in handpump hardware is arguably at its lowest in 30 years, and so galvanising interest to develop an international certification process, as well as further research is extremely difficult. Such an initiative would require not only investment, but also long-term commitment from the large agencies and governments that fund and implement programmes installing handpumps and their maintenance.

Consistently assuring the quality of the India II and III, and Afridev handpumps is not just a challenge for Burkina Faso but more widely. Concerns have also been raised regarding some Afridev components in another country, but the extent of the problem is not known. The India Mark II and III, as well as the Afridev are the choice of pump in many countries, with spare parts supply chains often well established. What is being witnessed, as documented in this report, is essentially a failure of "the market" to consistently deliver high quality materials. Addressing this failure requires needs solutions from within importing countries, such as Burkina Faso, but also internationally.

It is hoped that this short study will trigger interest by governments, and by research organisations, and international development agencies to explore ways to solve the problems of corrosion and poor quality handpump components. If this is not done, by inadvertent neglect, the global water supply community is arguably preventing rural populations in Burkina Faso and beyond from the benefits of a reliable, basic drinking water supply.

## References

- ABDOU, O (2008) RE: [groundwater\_rwsn] RE: :: New UPGro paper/report :: The impact of procurement and siting procedures on handpump functionality in Uganda, [Online] RWSN Sustainable Groundwater Development, 23 August 2018, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>
- ANON (no date) Statement provided by experts to the author anonymously via email, phone or Skype between 2017 and 2019
- ANSCOMBE, J (2018) [groundwater\_rwsn] RE: :: New UPGro paper/report :: The impact of procurement and siting procedures on handpump functionality in Uganda, [Online] RWSN Sustainable Groundwater Development, 18 August 2018, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>
- ANSCOMBE, J (2019a) [groundwater\_rwsn] Problem with Stainless Steel Handpump Components, [Online] RWSN Sustainable Groundwater Development, 5 April 2019, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>
- ANSCOMBE, J (2019b) [groundwater\_rwsn] Problem with Stainless Steel Handpump Components, [Online] RWSN Sustainable Groundwater Development, 1 May 2019, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>
- AOV (2018) Hand Pump >> India Mark II [Online], <[http://www.aovinternational.net/india\\_mark\\_II.php](http://www.aovinternational.net/india_mark_II.php)>, accessed 28 August 2018
- APEX INTERNATIONAL (no date) Hand Pumps for Safe Drinking Water, Apex International, Available on: <http://5.imimg.com/data5/XJ/LA/MY-855856/hand-pumps.pdf>, accessed 28 August 2018
- ARLOSOROFF, S., TSCHANNERL, G., GREY, D., JOURNEY, J., KARP, A., LANGENEGGER, O., and ROCHE, R. (1987) Community Water Supply: the handpump option. Rural Water Supply Handpumps Project, UNDP/World Bank, The World Bank, Washington D.C., USA, Available on: <http://www.rural-water-supply.net/en/resources/details/409>
- BAUMAN AND FUREY (2013) How three handpumps revolutionised rural water supplies in Africa, rural Water Supply Network (RWSN), Available on <http://www.rural-water-supply.net/ressources/documents/default/1-475-2-1363951079.pdf>
- BIS (2004) DEEPWELL HANDPUMPS, COMPONENTS AND SPECIAL TOOLS – SPECIFICATIONS, IS 15500 (Part 1 to 8):2004, BUREAU OF INDIAN STANDARDS
- BONSOR, H.C., OATES, N., CHILTON, P.J., CARTER, R.C., CASEY, V., MACDONALD, A.M., ETTI, B., NEKESA, J., MUSINGUZI, F., OKUBAL, P., ALUPO, G., CALOW, R., WILSON, P., TUMUNTUNGIRE, M. AND BENNIE, M. 2015 A Hidden Crisis: strengthening the evidence base on the current failure of rural groundwater supplies, 38<sup>th</sup> WEDC International Conference, 2015, Loughborough University, UK.
- CASEY, V, BROWN, L., CARPENTER, JD, NEKESA, J and ETTI, B (2016) The role of handpump corrosion in the contamination and failure of rural water supplies, Waterlines Vol. 35 No. 1., <<http://www.developmentbookshelf.com/doi/pdf/10.3362/1756-3488.2016.006>>
- DANERT, K, OUEDRAOGO, J.P, AMADOU, B and ZOMBRE, A (2017) Bonnes pratiques pour la réalisation de forages au Burkina Faso: Note de Mission 2017, Skat Foundation, Direction Générale des Ressources en Eau, Available at <https://www.rural-water-supply.net/en/resources/details/825>

- DANERT K, OUEDRAOGO JP, BALIMA A, AND ZOMBRE A (2019) Good practice for borehole drilling in Burkina Faso: 2017 Mission Report, Skat Foundation, Direction Générale des Ressources en Eau, Burkina Faso & UNICEF, Available at <https://www.rural-water-supply.net/en/resources/details/849>
- EMPA (2019a) Test Report 521421676, Empa Materials Science and Technology, Dübendorf, Switzerland
- EMPA (2019) Test Report 521421676\_2, Empa Materials Science and Technology, Dübendorf, Switzerland
- FUREY S. G. (2014) *Handpumps: where now?. A synthesis of online discussions (2012-2014)* , Skat Foundation , RWSN , St Gallen, Switzerland, Available at: <http://www.rural-water-supply.net/en/resources/details/614>
- HARVEY, P.A. AND SKINNER, B.H. (2002) *Sustainable Handpump Projects in Africa: Report on Fieldwork in Zambia* [pdf] Leicestershire, UK: Water, Engineering and Development Centre, Loughborough University <[http://wedc.lboro.ac.uk/docs/research/WEJW2/Report\\_-\\_Zambia.pdf](http://wedc.lboro.ac.uk/docs/research/WEJW2/Report_-_Zambia.pdf)>
- HARVEY, P.A., JAWARA, D. AND REED, R.A. (2002) *Sustainable Handpump Projects in Africa: Report on Fieldwork in Ghana* [pdf], Leicestershire, UK: Water, Engineering and Development Centre, Loughborough University <[http://wedc.lboro.ac.uk/docs/research/WEJW2/Report\\_-\\_Ghana.pdf](http://wedc.lboro.ac.uk/docs/research/WEJW2/Report_-_Ghana.pdf)>
- HARVEY, P. (2018) *Personal Communication*, Email RE: India II and II Specs used for purchase, 23 August 2018,
- INDIAMART (2018) *Deepwell Hand Pump* [Online], <https://dir.indiamart.com/impcat/deepwell-hand-pump.html>, Accessed on 29<sup>th</sup> Aug 2018
- LANGENEGGER, O. (1994) *Groundwater Quality and Handpump Corrosion in Africa*, UNDP-World Bank Handpumps Project, Available on: <http://www.rural-water-supply.net/en/resources/details/604>
- LIDDLE E. AND FENNER, R. (2018) *Review of handpump-borehole implementation in Uganda*, British Geological Survey, Groundwater Programme, Open Report OR/18/002
- MACARTHUR, J. (2015) *Handpump Standardisation in Sub-Saharan Africa: Seeking a Champion*. RWSN Publication 2015-1, RWSN , St Gallen, Switzerland, Available on <http://www.rural-water-supply.net/en/resources/details/652>
- MEERA and CEICO (2018) *INDIA MARK II Deep Well Hand Pump* [Online], < <http://www.meera-ceiko.com/India2.html>>, accessed 28 August 2018
- NORRIS, K (2019) [groundwater\_rwsn] Problem with Stainless Steel Handpump Components, [Online] RWSN Sustainable Groundwater Development 5 April 2019, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>
- SKAT/RWSN (2004) *India Handpump Specifications Revision 1-2004*, Skat/Rural Water Supply Network, St Gallen, Switzerland,
- SKAT/RWSN (2007) *India Handpump Specifications Revision 2- 2007*, Skat/Rural Water Supply Network, St Gallen, Switzerland, <<http://www.rural-water-supply.net/ressources/documents/default/1-327-2-1341317788.pdf>>
- UNDP-World Bank Water and Sanitation Program, Water and Sanitation Report 8 <<http://www.ruralwater-supply.net/en/resources/details/604>>
- WIKIPEDIA (2018) SAE steel grades [Online], [https://en.wikipedia.org/wiki/SAE\\_steel\\_grades](https://en.wikipedia.org/wiki/SAE_steel_grades) Accessed 21 Aug 2018

WIKIPEDIA (2019) SAE 304 stainless steel [Online],

[https://en.wikipedia.org/wiki/SAE 304 stainless steel#Difference between 304, 304H and 304L](https://en.wikipedia.org/wiki/SAE_304_stainless_steel#Difference_between_304,_304H_and_304L),

Accessed on 25 Apr 2019

VAN BEERS (2018) [groundwater\_rwsn] *NOW UNLOCKED: The role of handpump corrosion in the contamination and failure of rural water supplies* [Online] RWSN Sustainable Groundwater Development, 1 April 2018, Available from <[https://dgroups.org/rwsn/groundwater\\_rwsn](https://dgroups.org/rwsn/groundwater_rwsn)>

## Annex 1 A very short introduction to corrosion

Corrosion is the attack of the surface of materials by chemicals. Ferrous materials such as mild steel and galvanised iron can corrode, but concrete, glass, plastic and other materials can also corrode (Langenegger, 1994). Corrosion is the process of oxidation of metals, whereby they are returned to their natural state. There are three types of corrosion, all of which are oxidation-reduction (redox) processes as follows:

- Chemical corrosion – metal is in contact with oxidising constituents (e.g. oxygen, hydrogen, carbon dioxide).
- Electrochemical corrosion – the classic example is bimetallic, or galvanic corrosion, which occurs when two different metals are electorally connected and in contact with an electrolyte-
- Physico-chemical corrosion is caused by a combination of physical and chemical effects.

Corrosion can be greatly influenced by biological processes, especially the microbiological activity of iron bacteria.

*"...it is evident that the complex phenomenon of corrosion is governed by such a variety of chemical, physical, biological and metallurgical factors that a universal approach and solution is not possible. Equally evident is the well-recognised fact that no universal index exists for predicting corrosion in all types of water systems and for all water quality conditions"* (AWWA-DVGW, 1985)

Langenegger (1994) describes the most common forms of electrochemical corrosion which correspond to a galvanic element comprising an anode, a cathode, and electrical connection between them, and an electrolyte. In summary:

- Uniform corrosion is a relatively even attack on the metal surface. It mainly occurs on rising mains of handpumps, often combined with pitting.
- Pitting, or local attack is the local concentration of corrosion, either in very little spots or over relatively large areas. It occurs when anodic areas as stationary, and can be caused by imperfections of the materials, high oxygen or chloride concentrations, stray currents and damaged protective surface layers. Pitting can develop rapidly, and can result in perforation.
- Galvanic or bimetallic corrosion occurs where two dissimilar metals are electrically connected and in contact with an electrolyte, such as a galvanised iron pump rod with a brass pump cylinder. The corrosion rate is very much lighter than that of electrochemical corrosion.
- Crevice and concentration cell corrosion develops easily in crevices and under rivets and bolts.
- Intergranular or Intercrystalline corrosion only occurs at the interfaces of crystals, and is observed in stainless steel.
- Stress-Corrosion Cracking can develop in any metal under tensile<sup>8</sup> stress in a corrosive environment. It can lead to intercrystalline cracking (along the interface of the crystals) and transcrystalline cracking (through the crystals). Stress corrosion cracking may affect pump rods, particularly those under high tensile stress in deep pump installations. It characteristically result in shapeless cracking, which is typical of rod breakages.

### Handpumps

In galvanised rising mains exposed to corrosive groundwater, three different zones can usually be distinguished (a) no corrosion on the part of the pipe that it above the water level; (b) slight corrosion in the part occasionally submerged in water and (c) heavy corrosion in the part always covered by water, covered by a red-brown biofilm.

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<sup>8</sup> i.e. being pulled

Galvanization of iron is undertaken to protect it from corrosion. The quality of the galvanisation is very important, and this has led to specifications for the galvanisation of pipes. The standard for galvanized coating on rising mains and pump rods is a layer of zinc 60-70µm thick.

Field observations indicate that under moderately to highly corrosive groundwater conditions (pH<6.5), that the quality of galvanisation does not have a significant impact on the resistance of the handpumps and rising mains to corrosion. Langenegger (1994) found that the galvanisation of rising mains exposed to groundwater with a pH~6 was eaten away within approximately three to six months.

Pump rods are particularly vulnerable to corrosion. This is typically caused by galvanic corrosion, which occurs if the pump rods are made of galvanised iron and the pistons are made of brass.

#### Determining the source of iron in groundwater through testing

In order to determine the source of iron (i.e. is it due to corrosion or does it occur naturally) pump the well continuously and measure the change in iron concentration over time. If the iron concentration **decreases** rapidly within a few minutes of pumping, the main source is corrosion. In order to obtain reliable results, samples must be tested immediately after sampling the well site, or be preserved by acidification.

#### Corrosion effect on other parameters

Handpump corrosion affects not only iron, but also manganese, zinc, ammonium, nitrite, pH, free carbon dioxide, dissolved oxygen, alkalinity, and possibly other factors that affect water quality. The extent of effects depends on the corrosiveness and the natural composition of the groundwater.

#### Corrosion Products

Langenegger (1994) found that when rising mains and pump rods are in contact with water, they are generally covered with red-brown mud, known as a biofilm. This corrosion product is made up of iron, zinc, calcium, magnesium, potassium, sodium and aluminium as well as silica and organic matter from iron bacteria. The corrosion products range from very soft crusts (sometimes with a powdery texture) to hard crusts with a wide range of mixtures between the two. Whereas a very soft crust can be considered a typical biofilm, the hard crust is a protective coating. External surfaces of galvanised rising mains tend to be covered with biofilm which has a powdery structure when dried. In cases where the pH>6.5 and the conductivity was greater than 300µs/cm, the internal rising mains had a protective coating.



## Annex 2 Specifications and Standards

Table A2.1 Overview of India Mark handpump specifications and installation guides

Year	Publisher	Title	Remarks
2004	RWSN/Skat	India Mark Specifications Revision 1-2004	Superseded by revision 2 - 2007
2004	BIS	IS 15500 (Part 1 to 8):2004 Deepwell Handpumps, Components and Special Tools Specifications	<p><b>Connecting rod</b> – no clear “options”, but the following are mentioned. Notably in the dimension drawings (fig 4.21, fig 58), <b>only the electro-galvanising</b> is mentioned:</p> <ul style="list-style-type: none"> <li>• <b>Stainless steel X04Cr19Ni 9</b> of IS 6603<sup>9</sup> (section 5.2.1-pp 5)</li> <li>• <b>S.S 12 mm</b>(fig 2.5, pp 19)<sup>10</sup></li> <li>• <b>Mild steel</b> - electro-galvanised and passivated conforming to service condition No. 4 of IS 1573 (6.1 – pp 7 and <u>dimension drawings</u> -fig 4.21 – pp 58)</li> <li>• <b>Bright bar</b> (5.1.2 – pp 5 &amp; fig 2.1, fig 2.2 and fig 2.3)</li> </ul> <p>Plunger Rod –Standard &amp; Long:</p> <ul style="list-style-type: none"> <li>• <b>Stainless steel X04Cr19Ni 9</b> of IS 6603<sup>11</sup> (section 5.2.1; pp5)</li> <li>• <b>Stainless Steel 04Cr18Ni10</b> of IS 6603 (fig 3.5, pp 26 and fig 3.7, pp 28 and fog 3.9 – pp 30)<sup>12</sup></li> <li>• <b>Stainless Steel S.S. 304</b> (fig 3.13 – pp 34)<sup>13</sup></li> <li>• <b>Stainless steel</b> (<u>dimension drawings</u> -fig 4.22 and 4.2.3 – pp 58)</li> </ul> <p>Push rod (only for VLOM-65):</p> <ul style="list-style-type: none"> <li>• <b>Stainless steel</b> (fig 3.8 – pp29)</li> </ul> <p>Riser pipe:</p>

<sup>9</sup> With the following mechanical properties: Tensile strength 800 MPa, *Min*; Elongation 15 percent, *Min*

<sup>10</sup> FLP (Force Lift Pump)

<sup>11</sup> With the following mechanical properties: Tensile strength 800 MPa, *Min*; Elongation 15 percent, *Min*

<sup>12</sup> For SDWP (Standard Deepwell pump) and FLP (Force Lift Pump); VLOM-65; VLOM-50

<sup>13</sup> For stainless steel cylinder assembly SDWP and FLP alternative design)

Year	Publisher	Title	Remarks
			<ul style="list-style-type: none"> <li>• <b>Hot dip galvanised</b>, screwed and socketed pipe conforming to IS 1239 (part I) medium class (8.1, pp 8). <i>Notably this section also refers to section 6.4 which does not exist.</i></li> <li>• <b>Mild steel</b> (Fig 2.1, 2.2, 2.3, 2.4)</li> <li>• <u>No dimension drawings included in standard</u></li> </ul> <p>Socket for riser pipe</p> <ul style="list-style-type: none"> <li>• Manufactured from seamless pipe according to IS 1239 (part 2), or machined form solid bar conforming to Grade A of IS 2062 and shall be hot dip galvanised (8.1.2 - pp 9)</li> <li>• Galvanised according to IS 4759</li> <li>• <u>Dimension drawings</u> (fig 4.28, 4.28 and 4.30)</li> </ul>
2007	RWSN/Skat	India Mark Specifications Revision 2-2007	<p>Pump rod:</p> <ul style="list-style-type: none"> <li>• Mild steel or stainless steel (SS) options.</li> <li>• <b>SS advised for pH&lt;6.5.</b></li> </ul> <p>Riser pipe</p> <ul style="list-style-type: none"> <li>• Galvanised Iron only</li> </ul>
2008	RWSN/Skat	Installation & Maintenance Manual for the India Mark II Handpump <sup>14</sup>	No mention of non-suitability of galvanised iron riser pipe if groundwater pH<6.5
2008	RWSN/Skat	Installation & Maintenance Manual for the India Mark III Handpump <sup>15</sup>	No mention of non-suitability of galvanised iron riser pipe if groundwater pH<6.5

<sup>14</sup> <http://www.rural-water-supply.net/en/resources/details/328>

<sup>15</sup> <http://www.rural-water-supply.net/en/resources/details/329>

## Annex 3 Specifications for riser pipes, sockets/couplers and connecting rods

Table A3.1 Riser pipe and coupler/socket specifications

Description	Dimensions	Material	Standards	Remarks	Part no.	Reference
<b>Riser pipe/rising main - Galvanised Iron</b>						<b>RWSN 2007-2</b>
<b>Riser pipe</b>	Ø42.4/3.25 x 3000 mm	ST 320	ISO 630 <sup>16</sup> (ISO 559 <sup>17</sup> )	NB32, medium hot dip galvanized GI pipe (1 ¼")	C2365	RWSN 2007-2
<b>Socket</b>	Ø48 x 48 mm	ST 320	ISO 630 <sup>16</sup> (ISO 559 <sup>17</sup> )	For hot dip galvanized GI pipe (1 ¼")	C2366	RWSN 2007-2
<b>Riser pipe, UPVC with <u>threaded</u> UPVC coupling S0009335</b>					<b>UNICEF Supply Catalogue No.</b>	
<b>Riser pipe</b>	<ul style="list-style-type: none"> <li>• 40 NB x 3 m</li> <li>• 50 NB x 3 m</li> <li>• 65 NB x 3 m; OD 75mm x 5.5mm thickness</li> </ul>	uPVC	[all sizes] IS:12818-2010 <sup>18</sup> IS:15500-2004 <sup>19</sup> IS:4985-2000 <sup>20</sup>		-	S0009335

<sup>16</sup> Structural steels

<sup>17</sup> Steel tubes for water and sewage

<sup>18</sup> UNPLASTICIZED POLYVINYL CHLORIDE (PVC-V) SCREEN AND CASING PIPES FOR BORE/TUBEWELLS — SPECIFICATION (behind a paywall)

<sup>19</sup> Deepwell Handpumps, Components and Special Tools Specifications

<sup>20</sup> UNPLASTICIZED PVC PIPES FOR POTABLE WATER SUPPLIES — SPECIFICATION (behind a paywall)

Description	Dimensions	Material	Standards	Remarks	Part no.	Reference
<b>Coupler</b>	-	uPVC	[all sizes] IS:12818-2010 <sup>18</sup> IS:15500-2004 <sup>19</sup> IS:4985-2000 <sup>20</sup>	Injection molded three piece uPVC	-	S0009335
<b>Riser pipe, UPVC with <u>threaded</u> stainless steel (SS) coupler</b>					<b>UNICEF Supply Catalogue No. S0009335</b>	
<b>Riser pipe</b>	50 NB x 3 m	uPVC	EN/ISO 1452-1/2:2009 ISO 4065:1996 ISO 161-1:1996 BS-EN/ISO 11922-1:1997			S0009335
<b>Coupler</b>	Nominal diameter 50mm (Rp 2")	AISI 304L	ISO 2853:1993 RWSN/SKAT Rev 2-2007.			S0009335
<b>Riser pipe, all stainless steel with <u>welded</u> SS socket</b>					<b>UNICEF Supply Catalogue No. S0009335</b>	
<b>Riser pipe</b>	34mm ID, length of 3, 1 or 0.5 meter <sup>21</sup> , 38mm OD, ID 34mm, (2mm Thickness)	ERW AISI 304		<i>"Replacement parts... for INDIA MARK II &amp; III as per IS:15500-2004"</i>		S0009335

<sup>21</sup> Length +0/-25mm

Description	Dimensions	Material	Standards	Remarks	Part no.	Reference
<b>Riser pipe</b>	36mm ID, OD 42mm, (3mm Thickness) and 3 meter length.	AISI 304		"Quality of SS should be as per relevant Indian Standards (CrNi18/10) latest version"		S0009335
<b>Socket</b>	[for 34 and 36mm pipes above] Seamless threaded female sockets welded on one end <sup>22</sup> and threaded male on the other end <sup>23</sup> .	AISI 304				S0009335
<b>Riser pipe, stainless steel supplied in set with SS connecting rod S0005838</b>					<b>UNICEF Supply Catalogue No.</b>	
<b>Riser pipe</b>	32 mm (1"1/4)		ISO 2037, BIS:6603	<b>Gr4 CrNi 18 10</b>		
<b>Riser pipe thread</b>		AISI 304	ISO 7	Both ends male threaded		
<b>Coupling</b>	32 mm ND		ISO 2853	Threaded female		
<b>U-PVC Riser pipe with SS couplings ND 65 mm S0009155</b>					<b>UNICEF Supply Catalogue No.</b>	

<sup>22</sup> [of riser pipe]

<sup>23</sup> with plastic thread protector

Description	Dimensions	Material	Standards	Remarks	Part no.	Reference
<b>Riser pipe</b>	OD 80mm; -ID not less than 65mm; -Wall thickness not less than 6mm; Length: 2.9 m			<i>Nominal diameter in compliance with RWSN/SKAT specifications for India Mark III Hand Pumps, Revision 2-2007. Threading shall therefore comply with the riser pipe holder of such standard India Mark III/VLOM65 hand pumps.</i>	-	S0009155
<b>Coupling<sup>24</sup></b>	nominal diameter 65 mm (Rp 2"1/2)	ANSI 304L	ISO 2853:1993		-	S0009155

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<sup>24</sup> Details of o-ring not included here.

**Table A3.2 Connecting rod and pump rod specifications**

Description	Dimensions (mm)	Material	Standard	Remarks	Part no.	Reference
<b>Rod/pump rod - mild steel</b>						
<b>Rod</b>	Ø12 x 2990	E235	ISO 630	machined (bright)	C2372	RWSN 2007-2
<b>Connecting rod</b>						IS15500 (Part 1 to 8):2004
<b>Rod/pump rod - stainless steel</b>						
<b>Rod</b>	Ø12 x 2990	Stainless Steel	ISO 15510 <sup>25</sup>	machined, X5CrNi 18-9, bright	C2382	RWSN 2007-2
<b>Plunger rod-standard</b>						IS15500 (Part 1 to 8):2004
<b>Connecting Rod</b>	10.8 mm; 3m length <sup>26</sup>	AISI 304	BIS:6603	Gr4 CrNi 18 10		
<b>Connecting rod threading</b>	M12			Male thread at one end		UNICEF Catalogue S0005838
<b>Coupling</b>	M12	SS	Option B SKAT-RWSN Afridev Rev. 5-2007	Female threaded coupling welded at other end [of rod]		

<sup>25</sup> Stainless steels – chemical composition

<sup>26</sup> (+10/-0mm)

## Annex 4 Example of four India Mark II and III “produce details” from the UNICEF Supply Catalogue

Code	Name	Technical Specifications Referred To	Description
<b>S0009301</b>	Handpump, VLOM-65, MKIII-65, Variant 1 Tele	Bureau of Indian Standards IS: 15500:2004  SKAT International Specifications Rev. 2 - 2007	<p>FORESEEN FOR: 65 ND <b>uPVC riser pipe with Stainless Steel Couplings</b>, not included AND FOR: SS connecting rods with threaded couplers (same length) not included.</p> <p>The VLOM.65/India Mark III handpump features essentially the same above-ground equipment as per IS 15500-2004, complete, but adapted for below ground 65 mm ND riser pipes..</p> <p>The riser pipes are to be ordered separately (UNICEF catalogue number S0009155), being special design uPVC riser pipes with integrated Stainless Steel couplers, ND 65 mm, 3 m long. The Connecting rods are of Stainless steel, <b>10.8 mm</b> diameter, 3 m long, with M12 threaded ends, centralizers and couplers.</p>
<b>S0009335</b>	Handpump, SDWP, EDWP, VLOM, MKII&III, -Risers	IS:12818-2010 IS:15500-2004 IS:4985-2000	<p><b>General description:</b> selection of different <b>corrosion resistant Riser Pipe Sizes and types</b> for INDIA MKII &amp; MK III /SDWP, EDWP &amp; VLOM 50+65) types of hand pumps (PVC and/or Stainless pipe materials)</p> <p><b>RISER PIPE, UPVC WITH THREADED UPVC COUPLING</b></p> <p>1/- 40mm, length of 3 meters. Riser Pipe uPVC 40mm NB, 3 meters length, with injection molded three piece uPVC threaded couplers as per Bureau of Indian Standards IS:12818-2010, and as per IS:15500-2004.</p> <p>2/- 50 mm, length of 3 meters. Riser Pipe uPVC 50mm NB, for India Mark III handpump, 3 meters length, with injection molded three piece uPVC threaded couplers as per Bureau of Indian Standards IS:12818-2010, and as per IS:15500-2004.</p> <p>3/- 65mm, length of 3 meters, Riser pipe uPVC 65mm NB, for India Mark III handpump, 3 meters length, OD 75mm x 5.5mm thickness, with injection molded three piece uPVC threaded couplers and O-ring, as per Bureau of Indian Standards IS:12818-2010, IS:4985 (for dimensions, 75x10kg) and IS:1550 0-2004.</p>



Code	Name	Technical Specifications Referred To	Description
<b>S0009335</b>	Handpump, SDWP, EDWP, VL0M, MKII&III, -Risers	<p>Manufacture:</p> <ul style="list-style-type: none"> <li>EN/ISO 1452-1/2:2009</li> </ul> <p>Pipe dimensions:</p> <ul style="list-style-type: none"> <li>ISO 4065:1996</li> </ul> <p>Tolerances, wall thickness, ovality, nominal pressure rating (PN), nominal outside pipe diameter (OD)</p> <ul style="list-style-type: none"> <li>ISO 161-1:1996 and BS-EN/ISO 11922-1:1 997</li> </ul> <p>Dimensioned:</p> <ul style="list-style-type: none"> <li>ISO 2853:1993</li> </ul> <p>Nominal diameter in compliance with:</p> <ul style="list-style-type: none"> <li>RWSN/SKAT specifications for India Mark III Hand Pumps,Revision 2-2007.</li> </ul>	<p><b>RISER PIPE, UPVC WITH THREADED STAINLESS STEEL (SS) COUPLING</b></p> <p>4/- 50mm, length of 3 meters: Riser Pipe uPVC 50mm NB, manufactured from 100% virgin Unplasticized Poly Vinyl Chloride resin, dark grey or blue color, designed for a service life of at least 50 years at 20 degrees Celsius, in accordance with EN/ISO 1452-1/2:2009, certified non-toxic, suitable for drinking water, and exempt from CaCO<sub>3</sub> and/or other strength weakening additives.</p> <p>Pipe dimensions in accordance with ISO 4065:1996, tolerances, wall thickness, ovality, nominal pressure rating (PN), nominal outside pipe diameter (OD) etc. as per ISO 161-1:1996 and BS-EN/ISO 11922-1:1 997, 3 meters length with three piece Stainless Steel, threaded coupling:</p> <p>Each U-PVC pipe is fitted with a fully integrated seamless SS coupling system, either composed by 2 short, male threaded SS connection pipes, one each end, and a female threaded SS coupling; or by one short, male threaded SS connection pipe, one end, and one female threaded SS pipe at the other end, both pieces fully integrated with the PVC pipe.</p> <p>This pipe Coupling System shall be dimensioned with nominal diameter 50mm (Rp 2") as per ISO 2853:1993, all made from seamless Stainless Steel AISI 304L (1.4307). The nominal diameter is established in compliance with RWSN/SKAT specifications for India Mark III Hand Pumps,Revision 2-2007.</p> <p>Threading shall therefore comply with the riser pipe holder of such standard India Mark III hand pumps.</p>
<b>S0009335</b>	Handpump, SDWP, EDWP, VL0M, MKII&III, -Risers	<p>ERW AISI 304</p> <p>as per relevant Indian Standards ((CrNi18/10) latest version)</p>	<p><b>RISER PIPE, ALL STAINLESS STEEL WITH WELDED SS SOCKET</b></p> <p>6/- 34mm ID, length of 3 meters. SS Riser pipe; ERW AISI 304, 38mm OD, ID 34mm, (2mm Thickness) in 3 meter. Length +0/-25mm, with seamless threaded female sockets welded on one end and threaded male on the other end with plastic thread protector.</p> <p>7/ (as above but length of 1 meter).</p> <p>8/ (as above but length of 1 meter).</p>

Code	Name	Technical Specifications Referred To	Description
			9/- 36mm ID, length of 3 meters. SS Riser pipe ERW – suitable for use as riser pipe in deep well hand pumps, OD 42mm, ID 36mm (3mm Thickness) and 3 meter length, with seamless threaded female socket welded on one end and threaded male on the other end with plastic thread protector. Quality of SS should be AISI304 grade as per relevant Indian Standards ((CrNi18/10) latest version)
<b>S0009155</b>	Handpump, VLOM, Riser pipe, UPVC-SS, 65ND, 3m	<p>Manufactured in accordance with</p> <ul style="list-style-type: none"> <li>EN/ISO 1452-1/2:2009</li> </ul> <p>Pipe dimensions in accordance with:</p> <ul style="list-style-type: none"> <li>ISO 4065:1996</li> </ul> <p>Tolerances, wall thickness, ovality, nominal pressure rating (PN), nominal outside pipe diameter (OD) etc. as per:</p> <ul style="list-style-type: none"> <li>ISO 161-1:1996 and BS-EN/ISO 11922-1:1997</li> </ul>	<p><b>General description: U-PVC Riser pipe with SS couplings</b> ND 65 mm, 3 m long, supplied in set with SS connecting rod, for India Mark III-65/VLOM 65 Hand-Pumps.</p> <p><b>U-PVC RISER PIPE:</b></p> <p>The U-PVC riser pipe shall be manufactured from 100% virgin Unplasticized Poly Vinyl Chloride (U-PVC) resin, dark grey or blue colour, designed for a service life of at least 50 years at 20 degrees Celsius, and with following pipe dimensions: -OD 80mm; -ID not less than 65mm; -Wall thickness not less than 6mm; -Nominal pressure: 16 bar; Length: 2.9 meters</p> <p>Manufactured in accordance with EN/ISO 1452-1/2:2009, certified non-toxic, suitable for drinking water, and exempt from CaCO<sub>3</sub> and /or other strength weakening additives.</p> <p>Pipe dimensions in accordance with ISO 4065:1996, tolerances, wall thickness, ovality, nominal pressure rating (PN), nominal outside pipe diameter (OD) etc. as per ISO 161-1:1996 and BS-EN/ISO 11922-1:1997, with deviation of wall thickness to be not less than 6 mm.</p>
<b>S0009155</b>	Handpump, VLOM, Riser pipe, UPVC-SS, 65ND, 3m	<p>Dimensions:</p> <ul style="list-style-type: none"> <li>ISO 2853:1993</li> </ul> <p>Materials</p> <ul style="list-style-type: none"> <li>AISI 304L (1.4307)</li> </ul>	<p><b>STAINLESS STEEL COUPLING:</b></p> <p>Each U-PVC pipe is fitted with a fully integrated seamless SS coupling system, either composed by 2 short, male threaded SS connection pipes, one each end, and a female threaded SS coupling; or by one short, male threaded SS connection pipe, one end, and one female threaded SS pipe at the other end, both pieces fully integrated with the PVC pipe.</p>

Code	Name	Technical Specifications Referred To	Description
		<p>O-ring material</p> <ul style="list-style-type: none"> <li>ISO 4633:2002 and BS-EN-68 1</li> </ul>	<p>This pipe Coupling System shall be dimensioned with nominal diameter 65 mm (Rp 2"1/2) as per ISO 2853:1993, all made from seamless Stainless Steel AISI 304L (1.4307). The nominal diameter is established in compliance with RWSN/SKAT specifications for India Mark III Hand Pumps, Revision 2-2007.</p> <p>Threading shall therefore comply with the riser pipe holder of such standard India Mark III/VLOM65 hand pumps.</p> <p>To ensure full leakage proof, each joint shall be secured inside the assembly with a 5 mm rubber ring (O-ring) made of EPDM rubber or equivalent appropriate material as per ISO 4633:2002 and BS-EN-68 1, shore hardness of 60+/-5 IRHD or better.</p> <p>The complete riser pipe shall be certified for use with drinking water, i.e. exempt from toxic components, e.g. exempt from Lead etc. (as minimum to latest WHO Guidelines, NSF, EN standards, WRAS, or equivalent national standards).</p>
<b>S0005838</b>	Handpump, SDWP, INDIA MKII, SS-Riser, 32ND		<p><b>General Description:</b></p> <p>Riser pipe, stainless steel, 32mm nominal diameter, 3 meters length, for SDWP/EDWP Hand pump, INDIA MARK II type, supplied in set with SS connecting rod.</p> <p>Technical Specifications:</p> <p>Riser pipe, made of AISI 30 4 stainless steel conforming to ISO 2037, BIS:6603 Gr4 CrNi 18 10, or equivalent standard. Nominal diameter 32mm (1"1/4), both ends male threaded as per IS O 7, one end fitted with one female threaded coupling as per ISO 2853, the other end protected with a HDPE thread protector covering the entire length of the thread.</p> <p>In length of 3 metres. Nominal diameter: 32mm.</p> <p>Each riser pipe comes complete with: One Connecting Rod, made of Stainless Steel AISI 304 grade (BIS:6603 Gr4 CrNi 18 10), with M12 rolled male thread at one end, and M12 SS female threaded coupling welded at the other end (Option B SKAT-RWSN Afridev Rev. 5-2007).</p> <p>SS Rod Diameter: 10.8mm, Length of 3 meters (+10/-0 mm).</p>

## Annex 5 Notes on Stainless Steel Grades

"The **SAE steel grades** system is a standard alloy numbering systems for steel grades maintained by SAE International. In the 1930s and 1940s the American Iron and Steel Institute (AISI) and SAE were both involved in efforts to standardize such a numbering system for steels. These efforts were similar and overlapped significantly. For several decades the systems were united into a joint system designated the **AISI/SAE steel grades**. In 1995 the AISI turned over future maintenance of the system to SAE because the AISI never wrote any of the specifications" (Wikipedia, 2018).

Box A5.1 provides an overview of the different grades of stainless steel.

### Box A5.1 Stainless Steel Grades

[200 Series - 200 Series— austenitic chromium-nickel-manganese alloys]

- Type 202— austenitic general purpose stainless steel

[300 Series— austenitic chromium-nickel alloys]

- Type 304—the most common grade; the classic 18/8 (18% chromium, 8% nickel) stainless steel. Outside of the US it is commonly known as "A2 stainless steel", in accordance with ISO 3506.
- Type 304L— same as the 304 grade but lower carbon content to increase weldability. Is slightly weaker than 304.
- Type 316—the second most common grade (after 304); for food and surgical stainless steel uses; alloy addition of molybdenum prevents specific forms of corrosion. It is also known as marine grade stainless steel due to its increased resistance to chloride corrosion compared to type 304.

General Requirements

### Structural steel grades (ISO 630)

**Grade E 235** Chemical properties of test pieces:

C=0.22%max; P=0.055%max; S=0.055%max; Mn=1.5%max  
Tensile strength: 340-470 N/mm<sup>2</sup>

### Steel Pipes conform to ISO 559, "Steel tubes for water and sewage" (ISO 9339-1)

**Grade ST 320** Chemical properties of test pieces:

C=0.16%max; P=0.040%max; S=0.040%max; Mn=0.7%max  
Tensile strength: 320-460N/mm<sup>2</sup>

**Stainless steel** components shall be made of X5CrNi 18-9

Chemical properties of X5CrNi 18-9 in accordance with ISO 15510:

C=0.07%max; Si=1.0%max; Mn=2.0%max; P=0.045%max; S=0.015%max;  
N=0.11%max; Cr=16.0-18.0%; Mo=2.0-3.0%; Ni=10.0-13.0%  
Tensile strength: 510-710N/mm<sup>2</sup>

The nickel content of the stainless steel is particularly important in preventing corrosion.

Carbon content is also relevant, summarised as follows:

- "The carbon content of 304L (UNS 30403) is restricted to a maximum of 0.03%, which prevents sensitization during welding. Sensitization is the formation of chromium carbides along grain boundaries when a stainless steel is exposed to temperatures in the range of ~900 °F (480 °C)–1,500 °F (820 °C). The subsequent formation of chromium carbide **results in reduced corrosion resistance** along the grain boundary leaving the stainless steel susceptible to

*unanticipated corrosion in an environment where 304 would be expected to be corrosion resistant. This grain boundary corrosive attack is known as intergranular corrosion.*

- *The carbon content of 304 (UNS 30400) is restricted to a maximum of 0.08%. Thus 304 is not useful for corrosive applications where welding is required such as tanks and pipes where corrosive solutions are involved, thus, 304L is preferred. And its lack of a minimum carbon content is not ideal for high temperature applications where optimal strength is required, thus, 304H is preferred. Thus 304 is typically restricted to bars that will be machined into components where welding is not required or thin sheets that are formed in articles such as kitchen sinks or cookware that are also not welded.*
- *Carbon content has a strong influence on room temperature strength and thus the specified minimum tensile properties of 304L are 5 kilopounds per square inch (34 MPa) lower than for 304. However, nitrogen also has a strong influence on room temperature strength and a tiny addition of nitrogen produces 304L with the same tensile strength as 304. Thus, practically all 304L is produced as dual certified 304/304L, meaning it meets the minimum carbon content of 304L and also meets the minimum tensile strength of 304" Wikipedia (2019)*

## Annex 6 Detailed Test Results

Table 1 (page 16) provides an overview of the origin of the thirteen samples. The test results are set out in Tables A6.1 to A6.4.

**Table A6.1 Results for pipe no. 1-3**

Sample designation →	Sample 1	Sample 2	Sample 3	Expected values X04Cr19Ni9 <sub>1</sub>	Expected values X04Cr18Ni10 <sub>2</sub>
Element ↓					
Cobalt Co	0.25	0.04	0.09	n.s.	n.s.
Chromium Cr	17.88	14.11	12.30	17.50-20.00	17.00-20.00
Copper Cu	0.02	0.44	0.68	≤ 0.50	≤ 0.50
Iron Fe	Residue	Residue	Residue	n.s.	n.s.
Manganese Mn	0.78	10.00	10.49	≤ 2.00	≤ 2.00
Molybdenum Mo	<0.01	0.03	0.01	≤ 0.70	≤ 0.70
Nickel Ni	8.31	0.47	1.00	8.00-10.50	8.00-12.00
Phosphorous P	0.038	0.052	0.034	≤ 0.045	≤ 0.045
Silicon Si	0.37	0.37	0.36	≤ 1.00	≤ 1.00
Titanium Ti	<0.01	<0.01	<0.01	≤ 0.10	≤ 0.10
Vanadium V	0.07	0.03	0.07	n.s.	n.s.
Carbon C	0.08	0.11	0.20	≤ 0.08	≤ 0.08
Sulphur S	<0.01	0.007	0.009	≤ 0.030	≤ 0.030
Niobium* Nb	<0.1	<0.1	<0.1	≤ 0.200	≤ 0.200

≤ = less than/equal to

< = less than the detection limit for the method

n.s. = not specified

\* Method according to semi-quantitative XRF analysis, check for absence of niobium

<sub>1</sub> = Expected values according to steel key online version 2019

<sub>2</sub> = Expected values according to steel key online version 2019

Outside the specifications of the material expected values for X04Cr19Ni9 and X04Cr18Ni10

**Table A6.2 Results for pump rods no. 4-6**

<b>Sample designation → Element ↓</b>	<b>Sample 4</b>	<b>Sample 6</b>	<b>Sample 6</b>	<b>Expected values X04Cr19Ni9 1</b>	<b>Expected values X04Cr18Ni10 2</b>
Cobalt Co	0.14	0.03	0.04	n.s.	n.s.
Chromium Cr	18.36	13.61	12.42	17.50-20.00	17.00-20.00
Copper Cu	0.49	0.82	0.55	≤ 0.50	≤ 0.50
Iron Fe	Residue	Residue	Residue	n.s.	n.s.
Manganese Mn	1.65	9.58	9.79	≤ 2.00	≤ 2.00
Molybdenum Mo	0.38	<0.01	0.02	≤ 0.70	≤ 0.70
Nickel Ni	8.36	0.21	0.28	8.00-10.50	8.00-12.00
Phosphorous P	0.0483	0.083	0.067	≤ 0.045	≤ 0.045
Silicon Si	0.33	0.37	0.54	≤ 1.00	≤ 1.00
Titanium Ti	<0.01	<0.01	<0.01	≤ 0.10	≤ 0.10
Vanadium V	0.05	0.03	0.03	n.s.	n.s.
Carbon C	0.03	0.09	0.10	≤ 0.08	≤ 0.08
Sulphur S	0.021	0.010	0.011	≤ 0.030	≤ 0.030
Niobium* Nb	<0.1	<0.1	<0.1	≤ 0.200	≤ 0.200

≤ = less than/equal to

< = less than the detection limit for the method

n.s. = not specified

\* Method according to semi-quantitative XRF analysis, check for absence of niobium

1 = Expected values according to steel key online version 2019

2 = Expected values according to steel key online version 2019

3 = Within the measurement uncertainty of the method, still in the tolerance range

Outside the specifications of the material expected values for X04Cr19Ni9 and X04Cr18Ni10

**Table A6.3 Results for pipes Nos. 7, 9 and 10**

<b>Sample designation → Element ↓</b>	<b>Sample 7</b>	<b>Sample 9</b>	<b>Sample 10</b>	<b>Expected values<sup>1</sup> SS 304 / 304L Material number 1.4301 Designation X5CrNi18-10</b>
Cobalt Co	0.06	0.07	0.11	n.s.
Chromium Cr	11.80	12.54	12.59	17.50-19.50
Copper Cu	0.64	0.67	0.66	n.s.
Iron Fe	Residual	Residual	Residual	n.s.
Manganese Mn	10.64	10.12	10.08	≤ 2.00
Molybdenum Mo	0.03	0.06	0.07	n.s.
Nickel Ni	0.86	0.92	0.92	8.00-10.50
Phosphorous P	0.033	0.033	0.032	≤ 0.045
Silicon Si	0.37	0.38	0.38	≤ 1.00
Titanium Ti	<0.01	<0.01	<0.01	n.s.
Vanadium V	0.06	0.06	0.06	n.s.
Carbon C	0.23	0.22	0.25	≤ 0.07
Sulphur S	0.014	0.011	0.011	≤ 0.015
Nitrogen N	0.107	0.110	0.106	≤ 0.100

≤ = less than or equal to

< = less than the detection limit of the method

<sup>1</sup> = expected values according to the 2019 online version of the Key to Steel

n.s. = not specified

Outside the expected material specifications for SS 304 / 304L, X5CrNi18-10



**Table A6.4 Results for pump rod No. 8 and pipe sockets Nos. 11, 12 and 13**

<b>Sample designation → Element ↓</b>	<b>Sample 8</b>	<b>Sample 11</b>	<b>Sample 12</b>	<b>Sample 13</b>	<b>Expected values<sup>1</sup> SS 304 / 304L Material number 1.4301 Designation X5CrNi18-10</b>	<b>Expected values<sup>1</sup> STS303Cu (Republic of Korea)</b>
Cobalt Co	0.17	0.20	0.15	0.13	n.s.	n.s.
Chromium Cr	18.13	18.03	17.91	18.14	17.50-19.50	17.00-19.00
Copper Cu	1.82	0.68	0.31	0.03	n.s.	1.50-3.50
Iron Fe	Residual	Residual	Residual	Residual	n.s.	n.s.
Manganese Mn	1.81	1.16	1.07	1.19	≤ 2.00	≤ 3.00
Molybdenum Mo	0.33	0.08	0.23	<0.01	n.s.	≤ 0.60
Nickel Ni	8.51	8.33	8.28	8.42	8.00-10.50	8.00-10.00
Phosphorous P	0.032	0.034	0.037	0.038	≤ 0.045	≤ 0.200
Silicon Si	0.33	0.39	0.39	0.41	≤ 1.00	≤ 1.00
Titanium Ti	0.02	<0.01	<0.01	<0.01	n.s.	n.s.
Vanadium V	0.07	0.10	0.05	0.05	n.s.	n.s.
Carbon C	0.02	0.05	0.05	0.05	≤ 0.07	≤ 0.15
Sulphur S	0.004	<0.001	<0.001	0.003	≤ 0.030	≤ 0.150
Nitrogen N	0.060	0.064	0.067	0.049	≤ 0.100	n.s.

≤ = less than or equal to

< = less than the detection limit of the method

n.s. = not specified

<sup>1</sup> = expected values according to the 2019 online version of the Key to Steel