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## A practical course on filter assessment for water treatment plant operators

S. J. van Staden and J. Haarhoff

### ABSTRACT

Training of treatment plant operators in South Africa faces particular problems. First, the political changes in the past decade have led to a complete restructuring of local government. An integral part of the ongoing restructuring process is an aggressive programme for black economic empowerment. This brought many new faces into local government without the practical experience to which the water industry is accustomed, coupled with a massive displacement of technical skills from the sector. From 1989, the number of civil engineering professionals (engineers, technologists, technicians) has dwindled from 22/100,000 of the population to 3/100,000 of the population in 2007. Second, the Water Services Act (1997) of South Africa shifted the burden of water supply squarely onto the shoulders of district and local municipalities. The dilution of skills, coupled with increasing responsibility, makes it clear that the water sector in South Africa will have to train itself out of this predicament. As a result, the quality and focus of training programmes, especially at the operator level, is receiving renewed attention. This paper shares the experience of the development and refinement of a training course for filter assessment for operators over the past eight years.

**Key words** | filter assessment, filter course, skills development, technology transfer, treatment training

S. J. van Staden (corresponding author)  
J. Haarhoff  
Department of Civil Engineering Science,  
University of Johannesburg,  
PO Box 524,  
Auckland Park, 2006,  
South Africa  
E-mail: samvs@uj.ac.za

### THE PROBLEM WITH FILTER ASSESSMENT

It is widely believed that once engineered, a filter will work according to the specifications determined during its design. In addition, many filter operators are not familiar with the inner workings of a filter and, thus, take it for granted that a filter will behave according to its design specifications for the duration of its life without any significant change. However, in practice, many filters in treatment plants are found to have unacceptably dirty filter sand and backwash systems incapable of returning the filter media to a desired state of cleanliness, when visited a decade or more after commissioning. There is, thus, a world-wide awareness of the difficulty and importance of maintaining filter integrity in practice and there is constant development of new methods and approaches to deal with these difficulties. For these reasons, and in light of the dwindling skills in the civil engineering profession (Lawless 2007), the Water Research Group at the University of Johannesburg (up to 2004, the Rand Afrikaans

University) has compiled, presented and continues to present a course on filter assessment to interested parties in the water treatment industry. The feedback from the participants has been very positive throughout. This paper, therefore, explains the course's underlying philosophy and some details to guide others engaged in similar technology transfer programmes.

A principal difficulty of teaching filter assessment to novice operators is the fact that most of the important elements of a rapid gravity filter are invisible. From the upstream end, it looks like any other tank filled with water; from the downstream end, one sees a small overflow box amidst a forest of pipes, valves and actuators. Before the course can start to deal with filter assessment, an introduction is necessary to establish three things:

- The invisible filter elements have to be visualised including media layers, media supporting layers, filter nozzles,

underfloor details, flow paths of backwash air, backwash water, backwash waste and filtrate, control valves and required instrumentation.

- Precise vocabulary of all the filter elements needs to be established and enforced.
- All the visible elements have to be identified and named at a full-scale filtration plant (see Figure 1 below).

### A BALANCE OF LEARNING ELEMENTS

The course utilises a mix of five modes of learning. The first is a formal lecture of about 90 min, outlining the topic of the day – the ‘theory’ element. The lectures are structured in three steps:

- A *descriptive* part, where the relevant filter elements are described, illustrated or demonstrated. (e.g. how filter media is described in terms of its effective size and

uniformity coefficient; or handing out a selection of filter nozzles and pointing out the air measurement orifices and vent holes).

- An *explanatory* part, where the reasons behind the current practice are explained. (e.g. why the uniformity coefficient has to be kept to a certain minimum to ensure fairly homogenous fluidisation or what would happen if the vent hole in a filter nozzle were omitted).
- An *impact on filter condition* part, where the practical consequences of some technology failures on a filter are explained. (e.g. excessive media loss if the media effective size is too small or sand boils during backwash leading to a nozzle being blown out).

The second element of instruction comprises field work at a full-scale filter – the ‘boots and buckets’ element. Learners collect the equipment to do a series of filter assessment tests and follow the methods outlined in their study materials. This is done in groups of four to six

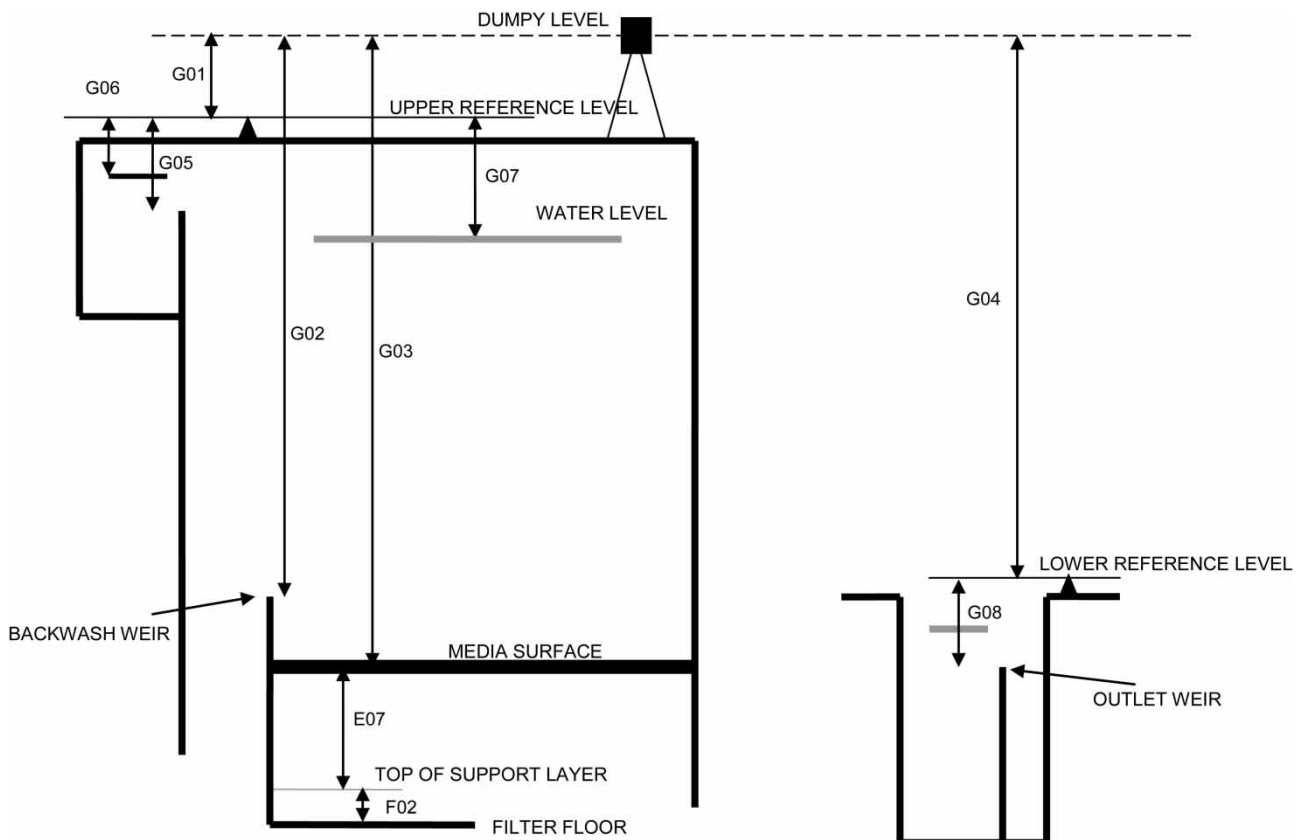


Figure 1 | Sketch of the typical filter elements within a filter, as would be measured by a survey of this kind (Haarhoff 2007).

people. Each group nominates a scribe for recording the data on site, while the others take the measurements or take the samples. This element requires close liaison with the treatment plant manager – a filter has to be set aside during this period and some assignments require an operator to do the necessary draining or backwashing. It was found to be important to have the course leader (or an experienced assistant) present during the fieldwork on site. Many opportunities arise while on site for further explanation, reinforcement of points made in the previous lecture, or, especially, responding to questions that were not put in class.

The third learning element takes place in the laboratory – the ‘dishwashing’ element. A number of the assignments rely on samples taken in the field, and then analysed in the laboratory. The laboratory work has been kept as simple as possible, bearing in mind that most of the novice operators have no or little analytical laboratory skills. Where possible, there should be at least one group member with some laboratory experience to guide the group in simple operations such as operating a chemical balance (fortunately, since the inception of our course eight years ago, there have always been laboratory personnel attending to learn more about the practical side of water treatment). As in the case of field work, the course leader or an experienced assistant should be on hand to exploit the spontaneous opportunities that arise for further explanation and instruction.

The fourth learning element takes the group back to the class room, but this time remaining in group context for the analysis and interpretation of the day’s results – the ‘making sense of it’ element. After being in the background during the fieldwork and laboratory sessions, the course leader takes the lead during this session. The groups analyse and present their results, which are checked by the course leader and interpreted. A data projector, with a spreadsheet program for data analysis, was found to work well to ensure that every learner can see the same results when they are discussed.

The final learning element comes at the very end of the course, when all the assessment results are compiled into a single report and an overall assessment is made, with recommendations on how the filter condition could be improved. This is done during an interactive session by the

course leader as a PowerPoint presentation, projected to all. In most cases, some of the senior management of the water utility are invited to attend the final 30 min of the course, where the summary presentation is made by the course leader – a simulation of how the results would be submitted after a formal filter assessment programme.

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## TIME MANAGEMENT

The course initially ran over five days, but this proved to be too disruptive to the schedules of the course leader, the attendees and the treatment plant management. After a few attempts, it was re-organised into a more compact three-day format, which has proved to be highly successful.

The three days are broken into four sessions each. The first session in the morning is spent on the lecture, when minds are alert. For the second session, the group heads to the full-scale facility to do the fieldwork. After the fieldwork, the tools are cleaned and stored and the attendees freshen up for lunch. (Clambering into the filter and working with filter media is dirty work!) After lunch, the laboratory work is done, with the final part of the day spent working on data analysis and interpretation.

A normal day of 8 h is followed. The four sessions are separated by a lunch break of 30 min and two tea breaks of 15 min each.

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## COURSE STRUCTURE AND FEEDBACK

The three course days each have a specific theme, namely ‘filtration’, ‘filter media’, and ‘filter backwash’. The first day is partly spent on an introduction and the identification and naming the different filter elements, as outlined earlier. The assignments for the first day are:

- Measure the sizes of the filter boxes and media beds
- Calculate the hydraulic loading with all filters working and when one is backwashed
- Measure the details and overflow depths at the filter boxes
- Calculate the total flow rate and hydraulic loading
- Assess the efficiency of the flow control system by checking whether filter flow rates are the same

- Slowly drain a dirty filter and survey the bed for media cracks and gaps between the media and the filter walls

The second day is devoted to the analysis of the filter media. On this day, somewhat less time is spent on field-work and more is spent in the laboratory. The assignments are:

- Sample the media in a representative way
- Measure the depth of the media bed in a number of positions with a thin metal probe
- Wash and dry the media for analysis
- Sieve the sand and determine the effective size and uniformity coefficient
- Measure the acid solubility of the media to check for calcite precipitation
- Determine the sphericity of the grains by stereoscopic observation
- Measure the density of the media
- Measure the porosity under three conditions – dry, after gentle deposition through water, and after compacting the immersed media by tapping the measuring cylinder. This demonstrates its variability.
- Calculate the theoretical headloss through the media bed.

The third day concentrates on the adequacy of the backwash system. The assignments are:

- Pilot column testing of the media to determine bed expansion during backwash and headloss during filtration
- Sampling media in a representative way after a single backwash
- Measuring the specific deposit that remains on the media after a single backwash
- Determining the actual rise rate of the backwash water to assist in calculating the actual backwash rate
- Collecting of wash water samples during backwash
- Measuring the amount of specific deposit that is washed out during backwash.

In addition to these assignments, the results obtained from the investigative assignments of all three days are then summarised in three further reporting assignments, namely:

- Summarising the data pertaining to the media
- Summarising the data pertaining to filtration

- Summarising the data pertaining to the backwash system

The practical assignments held the key to the success of the course. Assignments should be simple to retain the full understanding of all participants. The majority of changes over the years were made to the detail of the assignments. Some were dropped due to undue complexity or difficulty to perform (for example a dumpy level survey to determine the precise hydraulic gradient through the filter block, as most attendees were not familiar with either surveying or hydraulic theory). Some assignments were added (for example stereoscopic observation of media and measuring fluidisation of media in a transparent pilot column) to increase the intuitive understanding of phenomena not possible to observe at full-scale. Each of the 24 assignments currently used has a separate handout with clear instruction on some or all of five parts:

- List of equipment to be taken to site or the laboratory
- A step-by-step procedure
- A set of practical tips and notes to help with the practical execution of the prescribed procedure (for example some practical ways to fix a ladder to the side of a filter to be used as a water depth gauge)
- A pre-printed report sheet onto which all measured data are entered
- Instructions for the analysis of the data with supporting formulas.

This course has been presented 10 times in the last 9 years, with a total of 108 people attending the course, bringing the total to 418 attendee-days up to the time of writing. Structured feedback from the attendees indicated a high level of satisfaction. In the feedback from the latest course presented during July 2009, for example, the entire group agreed that the course was relevant to what they think they should know about filter assessment. The only 'negative' comments were that there was not enough time for discussion, and that some theory was not developed far enough (coming from an attendee with a degree in chemical engineering).

In addition to the feedback, we have had some Water Works implement multiple washes as the result of the outcomes of these assessments and make some changes to filters to prevent loss of media as well.

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## SUGGESTIONS AND FURTHER WORK

A process is underway to transcribe the course notes, which have continuously been refined over the years, into a textbook to be handed out to each course attendee. Such a textbook will be accompanied with more examples and spreadsheet software to improve the value as a future reference for operators tasked with filter assessment. Most treatment plants where the courses are offered do not have all the required equipment necessary for the course – a standard ‘toolkit’

of assessment equipment has been assembled which is available at short notice to accompany the presenters to field courses.

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