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Leak Detection Work for Unaccounted Water

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ABSTRACT: Rehabilitation of an existing pipe network depends on the Unaccounted Water (UW). Leak detection and water losses constitute the main reason for rehabilitation of existing networks. Field data was collected throughout leak detection, consisting of measurements of flow, pressure, consumption, location of leaks, length of pipelines, and correct diameters. Leakage can occur in reservoirs, transmission mains, and the distribution network. The objective of the leak detection program is to minimize losses and save quantities of precious potable water. This study presents details of a leak detection fieldwork. The location and methodology of leakage measurements are discussed, based on leakage management strategies. Leakage management strategies are classified into three groups, passive control, regular survey and leakage monitoring. The water balance calculation entails the measurement of distribution input and water consumption. Many techniques for detecting where leakage takes place in a network are discussed. The equipment used for leak detection are illustrated, including pipe locator, sound detector, and leak detector corrlator. Case studies of fieldwork are presented. Night Flow Test (NFT) is used to evaluate leak detection works for each zone. NFT is applied to measure flow and pressure in certain zones at night for the period (10 PM to 6 AM), whenever leakage is maximized. The case studies are selected from many countries where zones have different values of pressure, consumption and flow. The case studies are selected at the location where the ground level is varied and also where the ground level is flat. The results of analysis explain how to reach right conclusions and recommendations.

Keywords: Flow, Leak, Leakage Reduction, Unaccounted Water.

INTRODUCTION

Rehabilitation of an existing pipe network depends on the leak detection. Moursi *et al.* (1998 & 2000) studied leakage and its effect on an existing network. In this study complete survey of flow characteristics was obtained under different leakage conditions. Also, the flow characteristics (pressure, discharge, pipe diameter, etc.) were determined using different methodologies. The data collected covered the entrance of water work to the main trunk and all areas through branches of pipelines for different areas. The aim of leak detection was to minimize losses to save large quantities of precious potable water.

Lambert *et al.* (2005)used practical predictions of Economic Intervention Frequency (EIF) to calculate the short-run economic leakage level, with or without pressure management. The development of quick and practical methods for calculating economic leakage levels is a stated objective of the Water Losses Task Force. A barrier to this objective has now been removed, following the publication of a simple methodology to assess the economic annual volume of real losses from unreported bursts, for a policy of regular survey, using only three system-specific parameters. The study explains the rapid and practical approach, in the hope that Utilities currently undertaking insufficient active leakage control (or none at all) will be encouraged to adopt an ongoing basic intervention policy which is demonstrably economic. A further development of the methodology allows for the influence of pressure management, through changes in leak flow rates, new burst frequencies and repair costs. This permits rapid identification of situations where investment in pressure management should accompany or precede initiatives in active leakage control.

For this study, field data was collected throughout the leak detection work which consists of measurements of flow, pressure, consumption, location of leaks, length of pipelines, correct diameters etc. The

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field data was collected for the period from 1985 to 1989 in El- Behira water supply project, Binne (1989) and Moursi *et al.* (1998). The leak detection program was applied in Fayoum water network from January 2000 to December 2003 Royal Hosking Moghazy (2006). The details of leak detection fieldwork will be presented. The location and methodology of leakage measurements will be discussed based on the leakage management strategies prescribed by WHO (2001). The equipment used in leak detection techniques will be illustrated. At the end cases studies of fieldwork using the rules will be explained. Leak detection work and water losses studies constitute the main framework of rehabilitation for existing networks. The saved water can be used to meet the needs of increasing population and new industrial areas, and can help supply enough water to all networks 24 hours/day without the need for constructing new water works.

LOCATION AND METHODOLOGY OF LEAKAGE MEASUREMENTS

Leakage can occur in reservoirs, transmission mains, and the distribution network as follows:

Reservoirs

This can be measured by the reservoir drop test. Close the inlet and outlet valves and measure the drop in water level over time. If the reservoir has compartments, each can be monitored in turn. Drop tests are usually carried out at night to minimize disruption to the supply.

Reservoir Over Flows

Inspect float valves when the reservoir is at Top Water Level (TWL) to identify those which are passing. Estimate or measure the volume passing for the period when the reservoir is at TWL. Leakage from reservoirs is measured by conducting a drop test. The aim is to measure the rate of fall of the water level over the duration of the test, with both the reservoir inlet and outlet valves closed. The test should be done at night when demand is at a minimum.

Transmission Mains

Use insertion meters or clamp-on ultrasonic meters at each end of the main to calculate the change in volume flow rate. Alternatively, include the trunk mains in the distribution system measurement. These are the major mains for transmission between the sources and the distribution network, with relatively few connections from them to the secondary system. There are two methods of measuring trunk main leakage; one necessitates removing the main from supply: (by-pass method), and the other does not: (pairs of insertion meters).

The Distribution Network

Leakage in the distribution system can be measured as per one of the following methods:

1. Supply zone measurement is a method for measuring the night flow into a supply zone and includes main leakage in the trunk. Use a reservoir bulk meter to monitor flows at night (2 am to 4 am). Subtract the measured night use by large customers and the estimated night use by households. If there are no bulk meters, it may be possible to use another form of reservoir drop test.
2. Zone Meter Areas (DMAs) are small zones of 500–3000 households within a supply zone. Each DMA is a discrete zone, with a defined and permanent boundary. Flows into (and out of) each DMA are monitored by a flow meter. Night flow measurements are used to calculate leakage in the distribution system (distribution mains, service connections and fittings), after subtracting customer night use. Therefore leakage in the distribution network is derived from measurement of night flows into the system or part of the system.
3. The drop test method is similar to the method for measuring reservoir leakage, except that the reservoir outlet valve is open. Zone valves should be checked for drop-tightness, and the reservoir level monitored during the night. The fall in level is an indication of genuine night consumption and leakage. It can be assumed that genuine night consumption is very small, around 2 litres/property/hour, during the time of minimum night flow (usually between 2 am and 4 am).

LEAKAGE MANAGEMENT STRATEGIES

Leakage management strategies can be classified into three groups (WHO, 2001) as follows:

Passive Control

They are a reaction to visible leakage due to bursts or drops in pressure, which are usually reported by customers or noted by the company's staff. The method can be justified in areas with plentiful or low-cost supplies, and is often practiced in less developed supply systems where the occurrence of underground leakage is not so well understood.

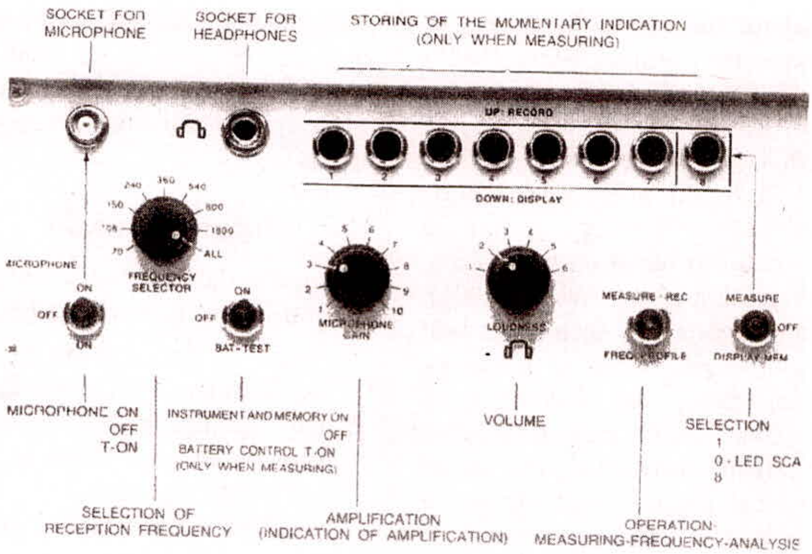


Fig. 1: Leak detector for Water Network system

Regular Survey (Sounding, Waste Metering)

It is a method of inspection (Figures 1 to 3) starting at one end of the distribution system and proceeding to the other, listening for leaks on pipe works and fittings, or reading metered flows into temporarily zoned areas to identify high-volume night flows.

Leakage Monitoring

It refers to monitoring the flows into zones in order to measure leakage and prioritize leak detection activities. This has now become the most cost-effective strategy for leakage management and the one most widely practiced.

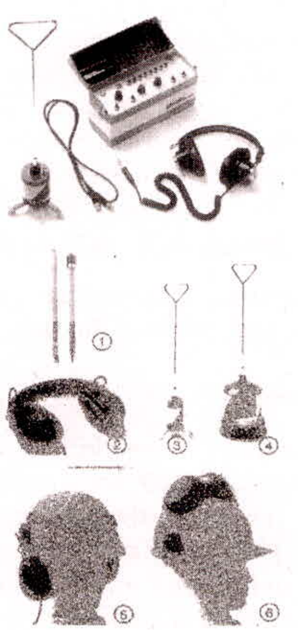


Fig. 2: Leak detector for water network systems

Zoning Principle

Ideally, a flow measuring system in a water distribution network would encompass the measurement of total flows to assist demand prediction and distribution management and also zonal flows, which will help the engineer to understand and operate the system in smaller areas, and allows leakage management and control to take place. The system is hierarchical, i.e., it covers a number of levels, beginning with measurements at the production end until the consumer's meter for an estimate of consumption through DMA and step test for certain zones.

WATER BALANCE CALCULATION

This is the measurement of distribution input and water consumption. It can be measured using a number of techniques; the most appropriate ones for the system under investigation should be selected. Ideally, all components of the water balance should be quantified over the same designated period, and expressed in Mega liters (Ml)/day.

Distribution Input

This step identifies all water sources and quantifies the water supplied. Measurement is by one or more of the following:

1. Existing production (bulk) meters, after checking for accuracy;
2. Summation of zone flows where there are existing zone meters;
3. Reservoir drop tests;
4. Checking of pump curves;

5. Insertion meters at points where there are no meters, e.g., upstream or downstream of treatment works;
6. Identifying all non-household customers; and
7. Identifying all household customers, and converting billing data to monthly or quarterly billing.

Measured Use

Billing records are used to quantify measured outputs from the system:

Period to an average daily flow in Ml/day.

Unmeasured Use

This step identifies un-metered households and other authorized unmeasured use:

1. Estimate use by un-metered households. Monitor a sample of households by meter, or estimate the per capita consumption; and
2. Identify and estimate unmeasured use by authorized users, e.g., municipal buildings, parks, fire services, tankers.

Unauthorized Use

This step identifies and estimates illegal supplies and theft by using the per capita consumption estimates to calculate the volume used.

Calculate Total Losses

Add together the volumes from the steps above excluding Distribution Input, and subtract from step Distribution Input. The residual is the total water loss from the system.

Calculate Leakage

The total water loss can be further broken down into leakage from reservoirs; overflows from reservoirs; leakage from trunk mains, leakage in the distribution system from the company's mains, service connections, and fittings; and each of these components can be quantified to improve the water balance calculation and to prioritize leakage management activities.

Other "Loses"

The water balance calculation can be further refined by identifying errors and malpractice. These are often called "management" losses, resulting in a shortfall of revenue for the water supplied.

LEAK DETECTION TECHNIQUES

There are a number of techniques to detect where leakage is taking place in a network. These techniques are explained in the following sections:

Sub-division of DMAs by Internal Valves

When monitoring shows that leakage has increased in a DMA, internal valves can be carried out to temporarily subdivide the DMA into smaller areas. If daytime closure of the valves causes supply problems they can be closed at night, and opened again before the morning high demand. Each sub-area is monitored in turn using the DMA meter. The result of each sub-division can be monitored by installing flow data loggers at each input meter in advance of the test. In large DMAs further sub-divisions can take place over several nights (see step-testing). At the end of the test the logged flow rates can be compared with the sequence of sub-division of the DMA. Leaky sub-areas are inspected and "normal" sub-areas are left alone. These meters would not normally be read, until DMA monitoring shows an increase in night flow. Internal valve may be carried out in conjunction with metering for further sub-divisions.

Variations of the Traditional Step-test

There are two main types of step-tests. The traditional technique is to progressively shut valves, working back towards the meter, and then returning to open valves when the test is completed. A more recent technique, helped by the improvement of flow meter and data logger technology, is to use a series of short steps, isolating sections of the DMA for a short time only. This technique requires a remote meter reading device, either a radio or mobile phone, positioned at the meter. Flow rates are transmitted to the site operators, enabling them to see the results of the valve closure immediately; these speed up the operation, and reduce the time the valves are left open. A one-man operation is also feasible, within the limits of health and safety guidelines (i.e., always two-men operation at night).

Establishing a Step-test Area

Step test area can be established as under:

- Determine the number of properties in the area.
- Determine the number of metered customers who use water at night.
- Estimate the number of un-metered non-domestic customers, taking note of those likely to use water at night
- Check the condition of valves to be operated during the test.
- Allocate numbers to the valves and note if they are closed clockwise or anti-clockwise.

Plans

Prepare a plan of the step-test area to show all flow characteristics and all other infrastructure components. Plans should be kept waterproof in a clear plastic wallet.

Preparation for the Test

The preparation can be carried out as explained in the case studies section.

Step-Test Procedure

In this method, the sections of the area downstream of the closed valve are without water during the test. Follow the sequence of closing valves right up to the meter, when the flow should be zero. In the close and open method, valves are closed at each step but re-opened once the meter reading has been noted. This overcomes the disadvantage of the isolation method, which can inconvenience night users. However, if a burst is identified on one of the steps, care should be taken when restoring the supply to avoid aerated or discolored water.

The back feed method uses the same sequence of closing as the isolation method, but each time a valve is closed another is opened behind it starting with the boundary valves. This allows the water to back feed from another part of the network maintaining supplies to the area.

LEAK LOCALIZING (NOISE LOGGING)

This technique has become popular over the last few years, and practitioners are increasingly using it as an alternative to step-testing. This technique can also be used as a routine survey to "sweep" a zone as per Figures 1 to 3. Although blanket sounding can be inefficient in terms of focusing on leaky areas, it does provide a systematic examination of DMAs, such as when a DMA is first commissioned. It also allows other non-leak faults to be identified. Leak location is carried out using at least one of the following pieces of equipment:

Basic Instrument

It is the sounding stick, which is used as a simple acoustic instrument, or electronically amplified. This technique is still widely preferred by the majority of practitioners, and is used for:

- blanket surveys, sounding on all fittings;
- sounding on valves and hydrants; and -confirming the position of a leak found by other instruments (ground microphone, leak noise correlator).

Ground Microphone

It can be assembled for use in either of two modes, contact mode and survey mode. The contact mode is for sounding on fittings, similar to an electronic listening stick. The survey mode is used to search for leaks on lengths of pipeline between fittings. The technique involves placing the microphone on the ground at intervals along the line of the pipe and noting changes in sound amplification as the microphone nears the leak position. When a leak is detected the ground microphone is used in either mode for leak location.

Leak Noise Correlator

It is the most sophisticated of the acoustic leak location instruments (Figures 4 to 6). Instead of depending on the noise level of the leak for its location, it relies on the velocity of sound made by the leak as it travels along the pipe wall towards each of the two microphones placed on conveniently spaced fittings (maximum 500 m apart). Hydrophones can also be used to enhance the leak sound in plastic pipes or large pipes. There is no doubt that the latest versions of the correlator can accurately locate a leak (to within 1.0 meter) in most sizes of pipe.

The instrument is portable and can be operated by one man, and it has the capability for frequency selection and filtering. The correlator can be used in two modes:

- as a survey tool to detect leaks in sections of the pipeline; and
- as a location tool to identify the leak position.

CASE STUDIES

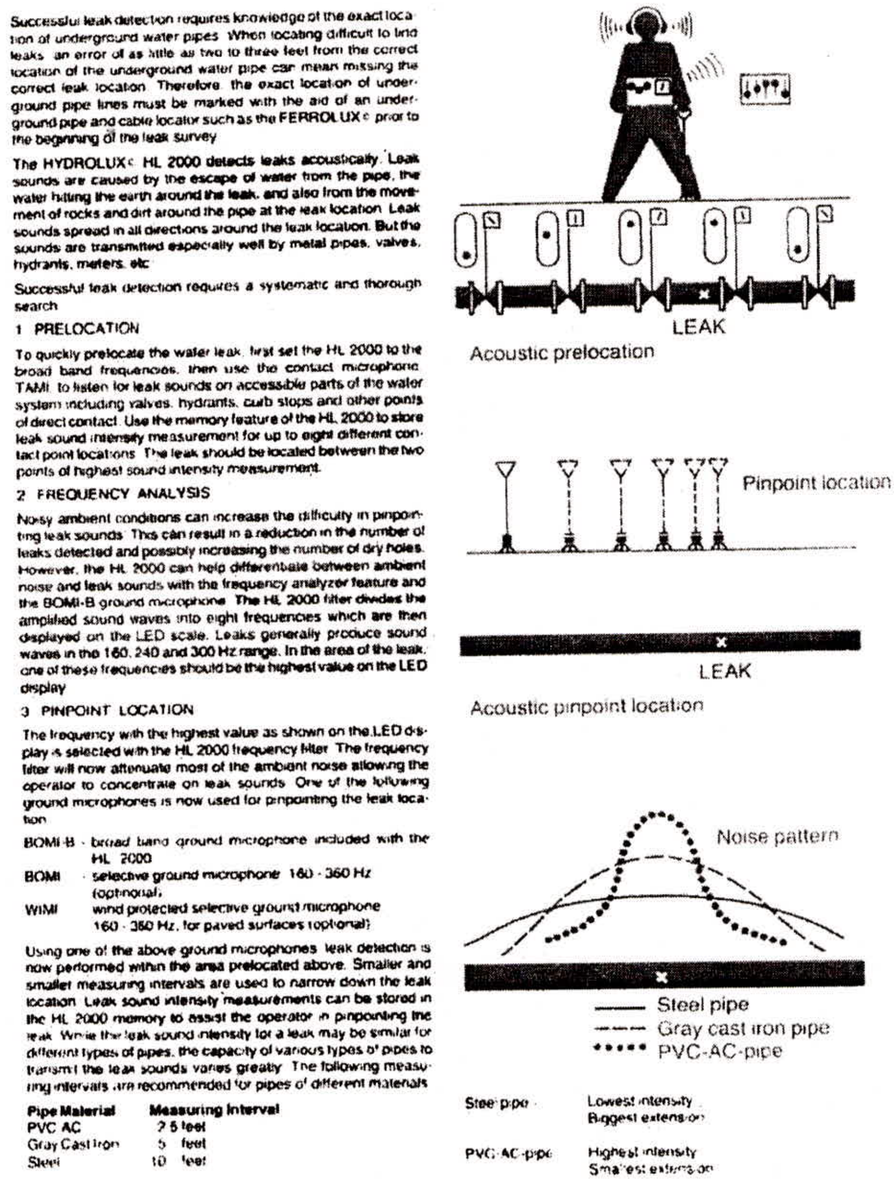
In this section, network characteristics for case studies are illustrated. The case studies will be used to simulate a developed model. The cases studied were selected from Unaccounted Water projects in Egypt at Fayoum, Governorate (Figure 7 for Egypt map and Figure 8 for Fayoum water network).

IBSHWAY ZONE 2 FAYOUM GOVERN RATE

The first case is Ibshway zone 2 (Figure) as follows:

General

The Unaccounted Water (UW) work was done for zone 2 in Ibshway Markaz, also referred to as New Qarun area. This zone includes the major part of one Local Unit, Qarun, with many Ezbahs. The boundaries of the UFW zone are indicated in Figure 9. Table 1 provides some basic data of the UFW zone.



Successful leak detection requires knowledge of the exact location of underground water pipes. When locating difficult to find leaks, an error of as little as two to three feet from the correct location of the underground water pipe can mean missing the correct leak location. Therefore, the exact location of underground pipe lines must be marked with the aid of an underground pipe and cable locator such as the FERROLUX© prior to the beginning of the leak survey.

The HYDROLUX© HL 2000 detects leaks acoustically. Leak sounds are caused by the escape of water from the pipe, the water hitting the earth around the leak, and also from the movement of rocks and dirt around the pipe at the leak location. Leak sounds spread in all directions around the leak location. But the sounds are transmitted especially well by metal pipes, valves, hydrants, meters, etc.

Successful leak detection requires a systematic and thorough search.

1 PRELOCATION

To quickly prelocate the water leak, first set the HL 2000 to the broad band frequencies, then use the contact microphone TAMI to listen for leak sounds on accessible parts of the water system including valves, hydrants, curb stops and other points of direct contact. Use the memory feature of the HL 2000 to store leak sound intensity measurement for up to eight different contact point locations. The leak should be located between the two points of highest sound intensity measurement.

2 FREQUENCY ANALYSIS

Noisy ambient conditions can increase the difficulty in pinpointing leak sounds. This can result in a reduction in the number of leaks detected and possibly increasing the number of dry holes. However, the HL 2000 can help differentiate between ambient noise and leak sounds with the frequency analyzer feature and the BOMI-B ground microphone. The HL 2000 filter divides the amplified sound waves into eight frequencies which are then displayed on the LED scale. Leaks generally produce sound waves in the 160, 240 and 300 Hz range. In the area of the leak, one of these frequencies should be the highest value on the LED display.

3 PINPOINT LOCATION

The frequency with the highest value as shown on the LED display is selected with the HL 2000 frequency filter. The frequency filter will now attenuate most of the ambient noise allowing the operator to concentrate on leak sounds. One of the following ground microphones is now used for pinpointing the leak location.

BOMI-B - broad band ground microphone included with the HL 2000
BOMI - selective ground microphone 160 - 360 Hz (optional)
WIMI wind protected selective ground microphone 160 - 360 Hz, for paved surfaces (optional)

Using one of the above ground microphones leak detection is now performed within the area prelocated above. Smaller and smaller measuring intervals are used to narrow down the leak location. Leak sound intensity measurements can be stored in the HL 2000 memory to assist the operator in pinpointing the leak. While the leak sound intensity for a leak may be similar for different types of pipes, the capacity of various types of pipes to transmit the leak sounds varies greatly. The following measuring intervals are recommended for pipes of different materials.

Pipe Material	Measuring Interval
PVC AC	2 5 feet
Gray Cast Iron	5 feet
Steel	10 feet

Fig. 3: Leak detector for water pipeline system

Water Sources

The zone is supplied by the New Qarun Compact Unit (The compact unit is small and rapid water treatment plant is constructed in the rural area to improve water supply.) through pipelines DN225Pvc reduced to DN200AC. The compact unit is the only single source of water supply, because no water flow is coming from the main water treatment plant through the network.

Service Connections

Table 2 provides details of the service connection. No unregistered or illegal connections were found during the period of UFW work in this zone.

Table 1: Objectives of UFW

Item	*Data*
Number of people living in zone	15,000
Known pipe length (km)-DN100 and above	21
Total estimated UFW (%)	>55
Pressure in area(m)	3
Total Objective UFW (%)	<45
Minimum service pressure in at the end of main line	8 m

Consumption Study

The consumption study (Table 3) is a very difficult subject, because consumption is affected by many factors.

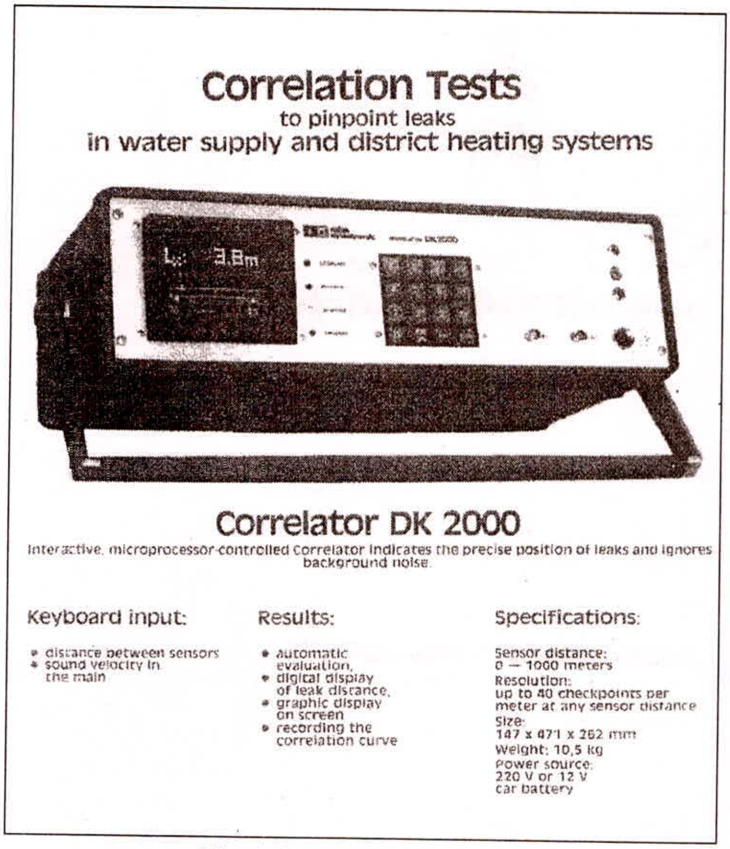


Fig. 4: Leak noise correlator

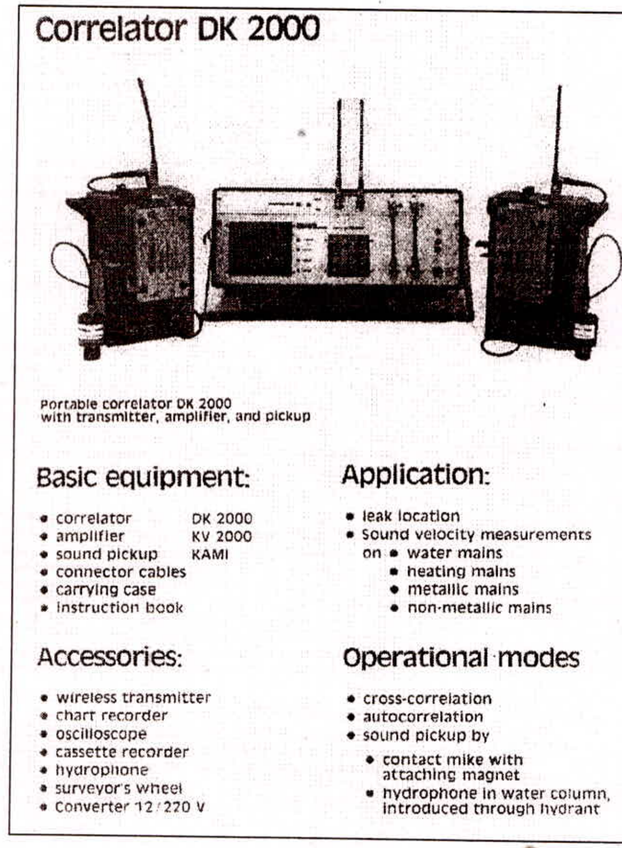
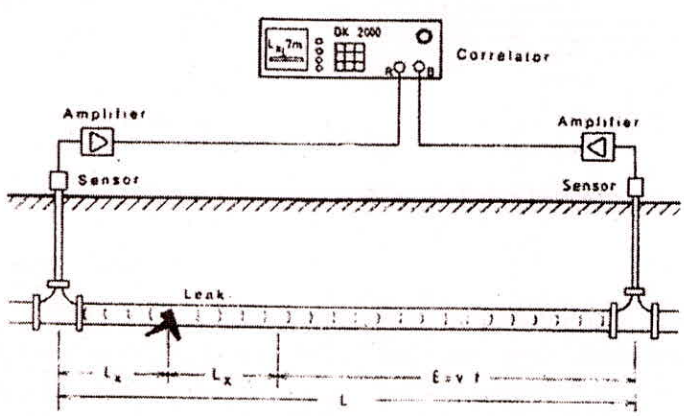


Fig. 5: Leak noise correlator

How it works

Water emanating from a pressurized main creates a characteristic noise propagating in both directions along the main. Sensors mounted on accessible fittings (hydrants or valves) pick up the arriving sound.

After filtering and amplification, the leak noise proceeds via cable or radio to the correlator for evaluation.



Correlator DK 2000

is used to measure the transit time of the leak noise and the position of the leak. It calculates these values automatically from the correlation peak of the leak noise coming from the two vibration sensors via special amplifiers.

Instrument-operator interaction by keyboard and video screen makes working easy and prevents faulty operation. Programming errors are displayed as such without erasing prior inputs. Special skills or knowledge are not required.

Leak position is displayed graphically on the screen. By proper choice of checkpoint density, a high resolution of the correlation function is obtained.

During the test, the input signals can be monitored by headphone and oscilloscope. The correlation function can be recorded on stripchart.

Fig. 6: Leak detector correlator

Fig. 7: Egypt map

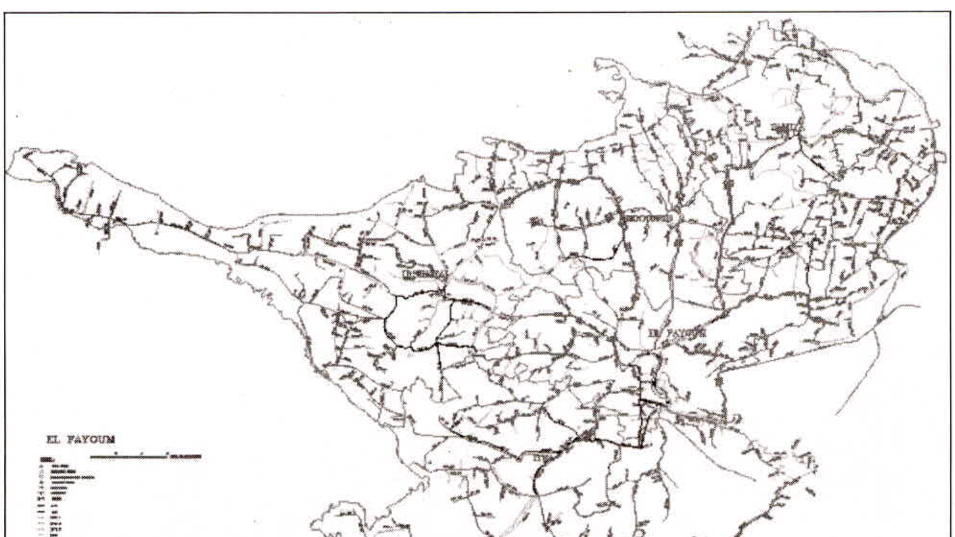


Fig. 8: Fayoum water network

So the period of study must be a minimum of six weeks in every season and measurements should be taken three times per week. The results of consumption studies should be selected as per the sample and the final rate of consumption is arranged in Table 3.

Table 2: Below Provides the Information on Service Connections

Connection Type	*Number*
House Connection	1,275
Pubic Tap	12
Mosque	23
Big Consumer	18
Governmental	0
Total	1,328

FAYOUM ZONE 1 & ZONE 1A FAYOUM GOVERN RATE

Second and third case studies are Fayoum zone 1- and zone 1A Fayoum governorate Figure 10 as per the following detail Royal Hosking (2002).

General

Zones 1 & 1A have about 35,000 people and have 3,924 house connections. Targets were set to reduce UFW to 35% of in flow, and increase pressure at the end of the zone to 15 m. The work was executed from August 2000 to January 2001 by UFW team and 108 leaks were repaired (2.9 leaks/km of pipeline), reducing leakage by more than 23,000 m^3/mth. The team had 6 data loggers (for pressure and flow), 6 insertion flow meters.

Table 3: Consumption under Normal Operating Conditions

Connection Category	*Sample Size*	*Persons/ Connection*	*Consumption/ Day*	*Consumption/ Month*
House Connection	90	7	0.63	18.9
Construction	7	1	1.2	36
Service	–	–	–	–
Commercial	12	3	1.0	30
Investment	4	10	2.5	75
Government	5	–	2.5	7.5
Mosque	5	–	7	198
Public Tap	6	–	9.6	288

Water Sources

Pipeline DN300AC supplies zone 1 and DN200CI supplies zone 1A. The DN450AC and DN600 PRC are the source for supplying the above mentioned two pipelines. DN450AC is the main source. The UFW zone contains an elevated tank at the start of the area in El Edwa. The EDWA tank is not in function and is still disconnected from the network. The area contains no compact unit treatment plants. No water flow was noted, coming from any other compact unit (for example, Demo Ezbah compact unit).

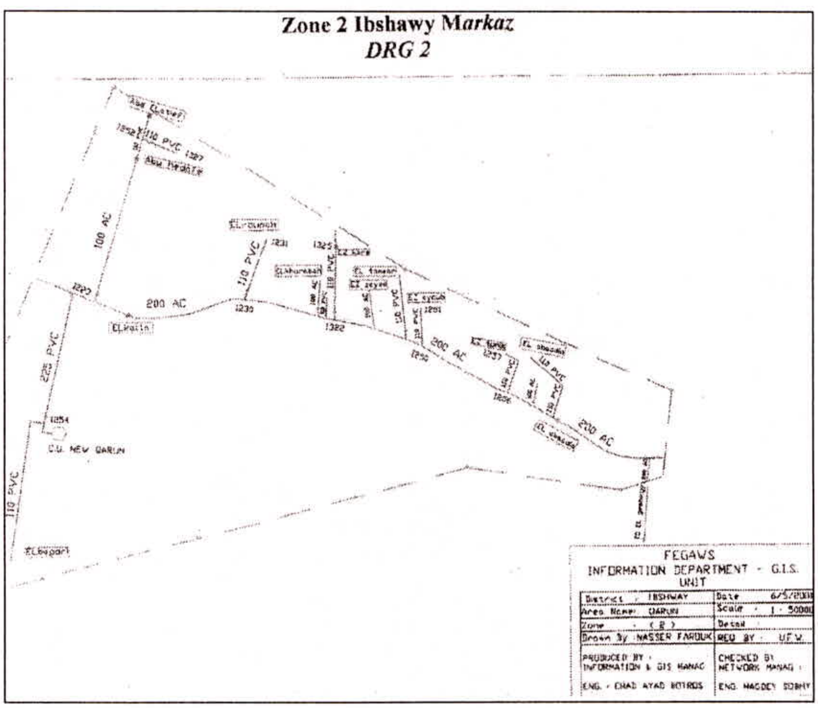


Fig. 9: Ibshway zone 2

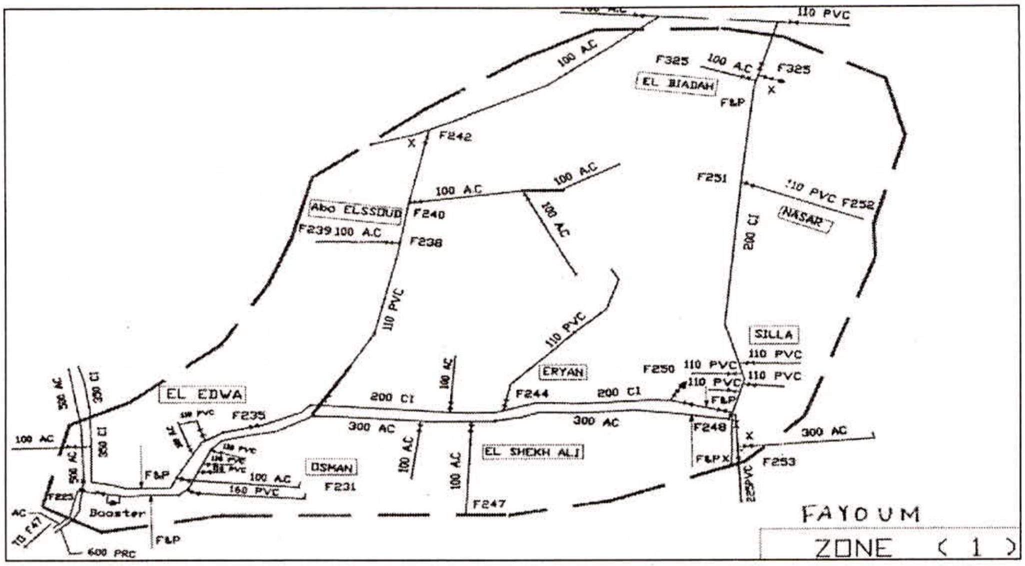


Fig. 10: Fayoum Zone 1&1A

Service Connections

Fayoum zones 1 & 1A Figure 10 have 3,924 house connections of which 3,014 are in El Edwa (including 770 of Abu Soud) and 910 in Sela. Only two illegal/unregistered connections were found. However, both of them are very large and important: The brick factory and the cow farm on the Abu Soud branch are considered as leakage.

CONSUMPTION STUDY

The consumption study (Table 4) is done in four Ezbahs: (1) The mother village El Edwa—with a sewer connection & high standard of living; (2) Othman Abd El Hay ezbah—a small village with high pressure (without sewer connection); (3) El-Sheikh ezbah; and (4) Nagib Arian ezbah—both with low standard of living and without sewerage connections. In this method the samples covered all types of standards of living found.

FIELD FLOW AND PRESSURE EVALUATION

Selecting of Zone Boundary

A zone boundary can be selected according to the following basic characteristics:

1. The length of pipeline DN100 and above should be less the 60 km.
2. The water supply sources are minimal.
3. The facilities to close any branch are available inside the zone and between zones.
4. The trunk main should not be included.
5. The pressure and flow are sufficient to feed most of the zone with water.

Measurements of Input and Output Main Flow

The measurement of input main flow will be done as follows:

1. Same time of starting repair. The main flow should be measured from all sources at the boundary of the network.
2. The input and output flow and pressure shall be measured continuously for periods of not less than three weeks.
3. The difference between the supplied flow demand and the outflow is equal to the leakage.

Analysis Flow and Pressure Measurement

Flow meter and a data logger were used to record the flow and pressure. The measurement of flow and pressure were repeated to obtain accurate recordings for all seasons during repair work. The evaluation of flow and pressure shows the period and the rates of maximum and minimum consumption, the difference between consumption flow and input flow is equal to the leakage value of this zone.

UFW Night Flow Test (NFT)

The step test or Night Flow Test (NFT) is the test applied to measure the flow and pressure at certain zones at night for the period (10 pm to 6 am) as follows:

1. The NFT test should be applied to the UFW zone.
2. Ensure that the valves at the beginning of branches are working.
3. Flow and pressure instrumentation is adopted and installed with a minimum of three days before the test.

Table 4: Measured Consumption under Normal Operating Conditions

Connection Category	*Sample Size*	*Persons/ Connection*	*Measured Consumption (m^3/day)*	*Measured Consumption (m^3/month)*
With Sewer				
House Connection	50	7	0.7	21
Construction	5	1	1.2	36
Service	–	–	–	–
Commercial	10	3	1.7	51
Investment	3	10	2.5	75
Governmental	5	–	2.5	75
Mosque	4	–	6.6	198
Without Sewer				
House Connection	90	7	0.4	12
Construction	7	1	1.2	36
Service	–	–	–	–
Commercial	12	3	1.0	30
Investment	4	10	2.5	75
Governmental	5	–	2.5	75
Mosque	5	–	6.6	198
Public Tap	6	–	9.6	288
Total	**206**			

4. A time table is prepared for the sequence of the valve closing and opening.
5. The branch valve must be closed according to the time table. The period between closing two branch is equal to 20 minutes. The direction of closing should start reverse to the flow from the end to the beginning of the zone.
6. The leakage is monitored during the test.
7. The reopening of the closed branch is considered as part of the test. The sequence of valve opening, the last valve closed is the first valve which should be opened with a period equal to 20 minutes.
8. The data collected from the flow meter and data logger is downloaded to the computer to use for the analysis of results. The leakage calculations are considered as explained by Moursi *et al.* (1998).

DISCUSSION OF RESULTS

The present section discusses field measurements before and after leak detection works. The adaptation of the results to the field measurements is achieved by alteration of the consumption value. Adjustment of the consumption is done by multiplying the consumption with a correction factor. The consumption correction factor is equal to a constant multiplied by the ratio of the square root of the pressure measured during the collection of the model input data to the square root of the pressure measured during consumption studies. The verification is carried out by comparing the field measurements before and after the leak detection program.

Figures 11 to 13 illustrate the pressure status before and after the leakage program. Tables from 5 to 8 establish the value of flow and consumption and leakage percentage. The case studies are selected from zone 1Edwa Fayoum Markaz indicated (Faym1), zone 1A Edwa Markaz indicated (Faym1A), and zone 2 Ibshaway Markaz indicated (Ibsh2).

Pressure Value Before and After Leak Detection Program

For zones faym1 and faym 1A and Ibsh2 the pressure values were measured before and after leak detection program. Figures 11 to 13 illustrate pressure values at high and low consumptions. For and zone Ibsh2 DN 200, the pressure rang before the leak detection program and had a range from 3 to 7 m which is under the target of 8 m. The pressure range for the same D200 of zone Ibsh2 (Figure 11) is 9 to 14 and has an average of 11.5 m achieving the target.

For zone faym1 DN300 the pressure rang before the leak detection program in Figures 12 and 13 and had a range from 8 to 15 m which is under the target value of 15 m. The pressure range for the same DN300 of zone faym1 is 11 to 22. Figure 13 has an average of 16.5 m, achieving the target. For zone faym1A DN200 the pressure rang before leak detection program had range from 4 to 12 m Figure 11 which is under the target value 15 m. The pressure range for the same DN200 of zone faym1A (Figure 12) is 11 to 21 has an average of 16 m achieving the target value.

The Percentage of the Leakage before and after the Leak Detection Program

For zone faym1 and faym 1A and Ibsh2 the leakage percentage were calculated based on the difference between flow and consumption. Both flow and pressure were measured at the same time before and after leak detection program. Tables 5 to 8 establish the details of flow and consumption and leakage value and percentage. For zone Ibsh2, the leakage. percentage was 49.2% (Table 5) before the leak detection program and 21.9% (Table 6) after the completion of the program. In all cases the consumption was increased.

The leakage percentage for zone faym1 before the program was 36.4% (Table 7) and after the program it was 12.3% (Table 8). For zone Faym1Athe leakage percentage was 39.5% before the program and 20.9% after the program of leak detection.

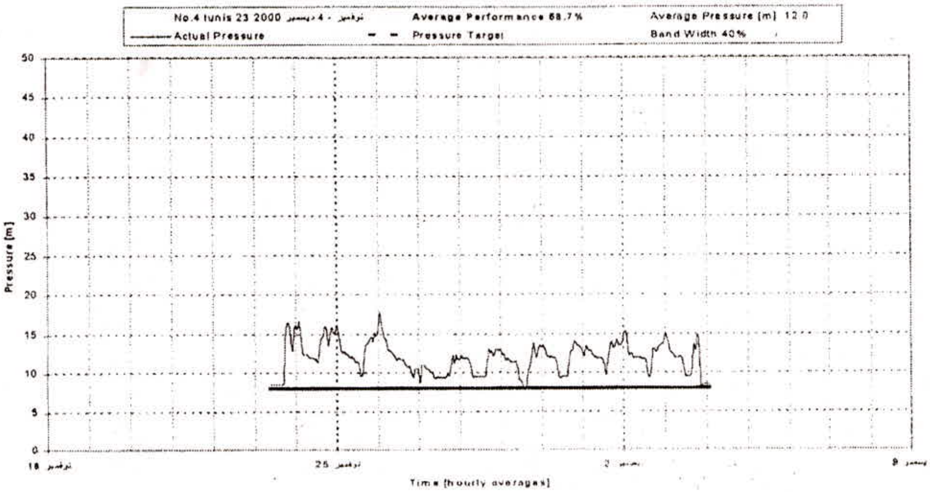
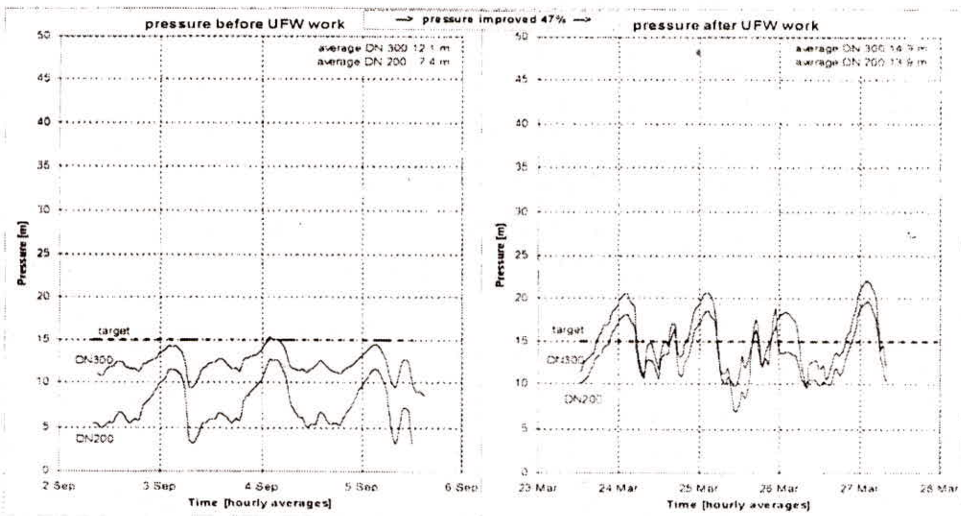


Fig. 11: Pressure performances before and after leak detection program in zone 2 Ibshawy



Figs. 12&13: Pressure performance before and after leak detection program in Fayoum zone 1&1A

Table 5: Result of Final Night Flow Test of Zone 2 Ibshawy

Ezbah	*Pipe DN*	*Flow in (m^3/h)*	*Flow out (m^3/h)*	*Flow net (m^3/h)*	*Consumption (m^3/h)*	*UFW (m^3/h)*	*UFW (%)*
For DN300AC							
Before closing any valve at new Qarun	100	92.3	0	92.3	71.95	20.35	22.0
Closing Abadia branch (Sela)	100	92.85	0	92.85	59.00	33.85	36.4
Closing Tunis branch	100	92.85	0	92.85	52.00	40.85	44.0
Closing Tunis branch	100	92.85	0	92.85	49.70	43.15	46.5
Closing Ayib branch	110	92.85	0	92.85	51.70	41.15	44.2
Closing Tourist branch	100	92.85	0	92.85	48.20	44.65	48.1
Closing Kareem branch	100	92.85	0	92.85	41.40	51.45	55.4
Closing Kharaba branch	150	92.85	0	92.85	37.80	55.05	59.3
Closing Rodah	100	87.3	0	87.3	33.40	53.90	64.0
Othman Ahamed afanday	100	86.3	0	86.3	33.40	52.90	61.2
Total Average for Zone		**91.7**	**0**	**91.7**	**46.6**	**45.1**	**49.2**

Table 6: Result of Final Night Flow Test of Zone 2 Ibshawy

Ezbah	*Pipe DN*	*Flow in (m^3/h)*	*Flow out (m^3/h)*	*Flow net (m^3/h)*	*Consumption (m^3/h)*	*UFW (m^3/h)*	*UFW (%)*
For DN300AC							
Before closing any valve at new Qarun	100	92	0	92	92.00	00.00	00.0
Closing Abadia branch	100	93	0	93	92.00	00.00	00.0
Closing Tunis branch	100	93	0	93	84.76	08.20	08.7
Closing Tunis branch	100	92	0	92	76.62	16.00	17.5
Closing Ayib branch	110	92	0	92	76.00	17.00	18.1
Closing Tourist branch	100	92	0	92	72.70	19.30	21.7
Closing Kareem branch	100	92	0	92	72.60	19.40	21.7
Closing Kharaba branch	150	92	0	92	58.80	33.20	36.6
Closing Kharaba branch	150	92	0	92	52.30	40.80	43.6
Closing Rodah	100	87	0	87	52.30	34.90	40.0
Othman Ahamed afanday	100	86	0	86	52.30	33.70	39.3
Total Average for Zone		**91.2**	**0**	**91.2**	**71.2**	**20.0**	**21.9**

Table 7: Result of First Night Flow Test of Zone 2 Ibshawy

Ezbah	*Pipe DN*	*Flow in (m^3/h)*	*Flow out (m^3/h)*	*Flow net (m^3/h)*	*Consumption (m^3/h)*	*UFW (m^3/h)*	*UFW (%)*
For DN300AC							
Before closing any valve at new Qarun	100	335	149	186	125.1	60.9	32.7
Closing main branch (Sela)	100	333	148	185	119.3	65.7	35.5
Closing El sheikh Ali branch	100	324	144	180	115.6	64.4	35.8
Closing Khafagah branch	100	324	144	180	123.8	56.2	31.2
Closing Abu El Soud Branch	110	313	200	113	93.3	19.7	17.4
First branch in El Edwa	110	309	201	108	67.7	40.3	37.3
Second branch in El Edwa	100	305	210	95	48.9	46.1	48.5
Closing third branch in El Edwa	100	298	220	78	32.1	45.9	58.8
Othman Abd El Hay	150	295	235	60	28.2	31.8	53.0
Average for DN300AC		**315**	**183.3**	**131.7**	**83.8**	**47.9**	**36.4**
For DN200CI							
Before closing any valve at El Edwa	100	187	46	141	105.6	35.4	25.1
Closing first branch (Sela)	100	190	45	145	102.2	42.8	29.5
Closing Nagib Arian	100	186	36	150	99.5	50.5	34.0
Closing Branshawy	100	184	35	149	90.5	58.5	39.3
First branch on El Edwa	100	181	35	151	68.4	82.6	54.7
Second branch on El Edwa	100	152	35	117	47.8	69.2	59.1
Average for DN200CI		**180**	**38.7**	**142.2**	**85.7**	**56.2**	**39.5**
Total Average for Zone		**495**	**222**	**273.9**	**169.5**	**104.4**	**38.1**

Table 8: Result of Final Night Flow Test of Zone 2 Ibshawy

Ezbah	*Pipe DN*	*Flow in (m^3/h)*	*Flow out (m^3/h)*	*Flow net (m^3/h)*	*Consumption (m^3/h)*	*UFW (m^3/h)*	*UFW (%)*
For DN300AC							
Before closing any valve at El Edwa	100	369	219	150	150.0	0.0	0.0
Closing main branch (Sela)	100	366	221	145	144.9	0.1	0.0
Closing El sheikh Ali branch	100	365	222	143	141.0	2.0	1.4
Closing Khafagah branch	100	358	210	148	148.0	0.0	1.0
Closing Abu El Soud Branch	110	339	223	116	114.9	1.1	1.0
First branch in El Edwa	110	330	227	103	86.8	16.1	15.6
Second branch in El Edwa	100	328	228	100	66.1	33.8	33.8
Closing third branch in El Edwa	100	326	237	89	47.6	41.3	46.4
Othman Abd El Hay	150	319	238	81	43.3	37.6	46.4
Average for DN300AC		**344**	**225**	**119**	**104.7**	**14.7**	**12.3**
For DN200CI							
Before closing any valve at El Edwa	100	149	20	129	105.6	23.4	18.0
Closing first branch (Sela)	100	144	20	124	102.2	21.8	17.5
Closing Nagib Arian	100	141	20	121	99.5	21.5	17.7
Closing Branshawy	100	131	23	108	90.5	17.5	16.2
First branch on El Edwa	100	118	26	92	68.4	23.6	25.5
Second branch on El Edwa	100	104	28	76	49.8	28.2	37.1
Average for DN200CI		**131**	**22**	**108**	**85.7**	**22.6**	**20.9**
Total Average for Zone		**475**	**247**	**228**	**190.4**	**37.3**	**16.4**

CONCLUSIONS

The following conclusions are drawn:

1. Leak detection program can save significant quantities of water.
2. The consumption is increased, once the leakage value was decreased
3. The leak detection program must be applied on a regular basis.
4. The accuracy of the result is a function of the equipment used and the correct methodology.

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