ENERGY AUDITS AND RETROFITS OF DEEP-WELL TURBINE TUBEWELLS

G.S. Saqib & Shaukat Khan
National Energy Conservation Centre (ENERCON),
Ministry of Planning and Development,
Government of Pakistan, Islamabad

Complete energy audits of 64 tubewells, installed in metropolitan area of Islamabad, Pakistan, were carried out in order to evaluate the performance of the pumping system and assess the possible potential for energy savings through a programme of routine energy audits and retrofits. Overall average efficiency was 39% against a maximum average attainable level of 70%. Fifty out of 64 tubewells were below the minimum acceptable overall efficiency level of 50%. This low overall efficiency level was mainly attributed to oversized pumps and motors for their application and worn pumpig parts. More than 30 electric motors had efficiency of less than 83% against the maximum attainable level of 90%. The major cause of this low efficiency was underloading Most of the motors were operating below 60% loading. The average measured transmission efficiency was 98% which is 99% of the maximum attainable level of 99%. The transmission lines were generally found to be satisfactory except a few ones which had a transmission efficiency of 95% or less and motors had high initial frictional torque.

It has been estimated that if overall efficiency level is improved to an average of 65% through a comprehensive retrofit/repair programme, total energy savings of about 4.8 million kWh in the current estimated energy usage of about 12 million kWh per year valued at more than Rs. 7 million (@ 21 pumping hours per day and Rs. 1.50 per kWh) can be realized only from Islamabad area.

INTRODUCTION

There are more than 70 tubewells for supply of water in the metropolitan area of Islamabad, Pakistan. Majority of these tubewell pumps are vertical line shaft turbines, and a few ones are centrifugal pumps referred to as shallow wells. Some tubewells discharge water directly to the water distribution system, while others discharge into underground sumps or overhead storage tanks. In addition to the tubewells used to pump water from underground aquifers, there are a number of transfer pumps used to pump water from underground sumps to the distribution system. These sump-transfer pumps were not audited during this study.

A kilowatt-hour meter, 3 voltmeters and 3 ammeters are installed on most of these tubewells. These tubewells are also equipped with a control valve and a non-return valve at the pump outlet. Some of the pumps are fitted with a discharge flow meter and a discharge pressure gauge. The depth of bore in these wells ranges from about 60 to 90 meters (200 to 300 feet). Most turbine pumps are installed at a distance of about 37 meters (120 feet) from the surface. An access hole is available to sound the static as well as pumping water levels for all pumps and at places these were found choked. The prime movers used on these tubewells are electric motors, in the range of 11 to 45 kilowatts (15 to 60 horsepower). The average power consumed as measured in this study was 20 kW and ranged from 5 to 52 kW. An overall average measured discharge of these tubewells was 20 L/s and ranged from 3 to 56 L/s (0.11 to 1.98 cusec).

The averages of discharge pressure head and system pressure head were 29 meters (ranging from 1 to 75 m) and 24 meters (ranging from 1 to 67 m) measured immediately before and after control valves on delivery line. Many of the control valves had to be closed partially to match oversized pumps to well yields which caused huge energy loss due to friction offered by these partially closed valves. This study aimed at determining the current energy usage and efficiency level of tubewell machinery operating in the metropolitan area of Islamabad, Pakistan and to assess possible potential for energy savings through a programme of routine energy audits and retrofits (including adjustment and repair of equipment identified as having low operational efficiency).

Audit procedure: General guidelines and instructions given in the Tubewell Energy Audit Manual (ENERCON, 1989) were followed for carrying out energy audits in this study. Detailed procedure for data recording and acquisition is contained in the CDA Tubewell Energy Audit Report (ENERCON, 1990). Flow measurements were made using totalizing flow meters and/or Collin's Flow Tube and the discharge pressure was measured using an electronic pressure transducer and/or test grade dial pressure gauge. An electric power-analyzer (Power-Master) was used to measure electric power input to motor, voltage and current in each phase and power factor of motors. Depth to static and pumping water levels was measured using an electric well sounder. The depth to static water level was measured after the pump had been stopped for about 30 minutes.

During the time the pump was switched off, measurement instruments were installed. Three data sets, each comprising power input to motor, voltage and current in each phase, power factor of motor, motor speed, discharge, depth to pumping water level, discharge pressure (before control valve) and system pressure (after control valve), were obtained with an interval of 15-20 minutes after start of the tubewell.The measurement of above mentioned parameters provided bases for computation of overall efficiency as well as component efficiency of tubewells under the study. The results of this study were compared against the maximum attainable efficiency levels for tubewells comprising turbine pumps and electric motors. The maximum attainable efficiency levels given in the CDA Tubewell Energy Audit Report (ENERCON, 1990) were used as a reference.

RESULTS AND DISCUSSION

Discharge, power and head: An overall average of the measured discharge was 20 L/s and ranged from 3 to 56 L/s (0.11 to 1.98 cusec). Very low discharge (10 L/s or less), associated with low pump and/or piping efficiency is mainly attributed to improper matching of pump to its application and at least 11 tubewells were such which fell under this category. The average power consumed was 20 kilowatts, ranging from 5 to 52 kilowatts. The rated power of electric motors installed ranged from 11 to 45 kilometers (15 to 60 horsepower). At least 30 out of 64 motors were running at less than 60% loading. This indicated that majority of motors were running unloaded which resulted in low motor efficiency and wastage of energy.

Total field head is made up of components due to discharge pressure head at the pump outlet (before control valve) and the elevation head required to lift water from pumping water level in the well to the ground surface. The total system head is defined to be the sum of elevation head required to lift water from pumping water level and the head to maintain the water supply in the delivery system. The average system head measured was found to be 44 meters of water (144 feet of water) and ranged from 12 to 96 meters of water (39 to 315 feet of water). The average distance from pumping water level in the well to ground surface was 20 meters (65 feet) and ranged from 4 to 36 meters (13 to 118 feet). The system pressure heads showed a wider degree of variation as some tubewells supplied water direct to distribution system exhibiting a low system pressure head and some were discharging water to underground or overhead tanks indicating high pressure heads. The average system pressure head was 24 meters of water (80 feet of water) and ranged from 1 to 67 meters of water (3 to 220 feet of water). Similarly, the discharge pressure head, which is characterized by the distribution system and the position of control valve, whether partially closed or fully opened, also varied from 1 to 75 meters of water (3 to 246 feet of water) with an average of 29 meters of water (95 feet of water).

The difference in Field head and System head (or the difference in discharge pressure head and system pressure head) is the measure of the head/energy lost particularly due to friction offered by the partially closed control valve. The frequency distribution of difference in Field and System heads indicated that 9 tubewells were such where head loss due to partially closed control valves was 5 meters or more causing excessive energy loss.

Overall efficiency: The maximum attainable overall efficiency of a tubewell, inclusive of pump, motor, transmission and piping, is about 70%. Overall tubewell efficiencies in the range of 50 to 70% may be considered acceptable for practical purposes. A tubewell having overall efficiency less than 50% is regarded substandard and corrective measures are generally cost effective. A frequency distribution of the measured overall efficiency is presented in Figure 1. The average overall efficiency was 39% which ranged fom 8 to 73%. The performance of 14 out of 64 tubewells was satisfactory i.e. the overall efficiency of these tubewells ranged from 50 to 73% and pump efficiency was between 65 to 82%. The remaining 5o tubewells were below the minimum acceptable overall efficiency level of 50%.

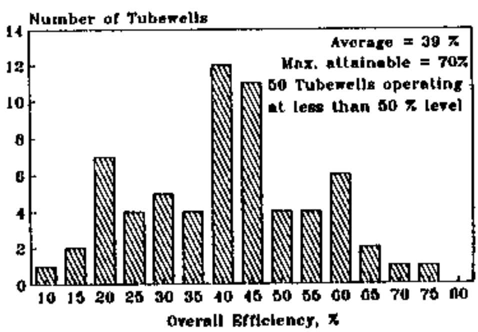

Fig. 1. Frequency of distribution of overall efficiencies.

The low tubewell overall efficiency may be attributed to the two main factors, i.e. wear of pumping components and improper matching of pump to its application. A well designed newly installed tubewell declines in its performance/efficiency with passage of time not only because of worn pumping components but also because the pump becomes oversized due to decreased well yields. This results in excessive specific draw downs and energy use. If a pump is improperly matched with its application, a modification in pump and/or well rehabilitation is required. It involves adding or removing of pump stages, changing the pump size usually with a smaller one and/or rehabilitation of well. If the decline in overall efficiency is due to wear of pumping components, it is advisable to replace the worn components with the replacement parts supplied by the original manufacturer as the use of copied parts can significantly reduce the benefits of pump repair and original efficiency is often not restored.

Pump efficiency: A frequency distribution of measured pump efficiencies is given in Figure 2. The average pump efficiency was 51% which was about 64% of the maximum attainable level of about 80%. The measured pump efficiency ranged from 11 to 82%. Thirty-one out of 64 pumps had pump efficiency of 50% or less. The inefficiency of most pumps accounted for major portion of low overall efficiency encountered in the tubewells of the metropolitan area under study.

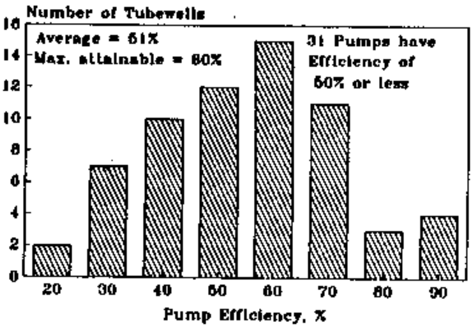

Fig. 2. Frequency of distribution of pump efficiencies.

Motor efficiency: A frquency distribution of motor efficiencies is presented in Figure 3. The average measured motor efficiency was 83% and ranged from 71 to 90%. Motor sizes, in most cases, matched to the design requirements of respective pumps. Thirty-two out of 64 motors had the efficiency of 83% or less. Major cause of this low efficiency was generally underloading. The motors were running underloaded only at installations where pumps had become oversized for the available discharge. Correction of motor sizing should, therefore, be done only when pump sizing is corrected.

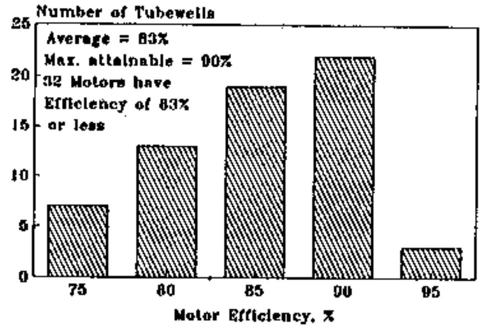

Fig. 3. Frequency of distribution of motor deficiencies.

Transmission efficiency: The average measured transmission efficiency was 98% and ranged from 92 to 99%. The average efficiency was 99% of the maximum attainable level of 99%. The transmission lines were generally found to be operating satisfactorily except a few ones which had a trasnmission efficiency of 95% or less and motors had a high initial frictional torque.

Piping efficiency: The average piping efficiency was 92% and ranged from 45 to 99. Twelve out of 64 tubewells had piping efficiency of 90% or less. The major cause of low piping efficiency was partially due to closed valves. In case of an oversized pump, it tries to draw more water than the well is able to deliver and the draw down increases to a point at which the pump inlet is no longer submerged. This results in a situation where the pump output fluctuates. A common measure, in this case, is to partially close control valve at the pump outlet thereby decreasing the flow rate and greatly increasing discharge pressure. However, a great deal of energy goes waste in this way.

Specific draw down: The specific draw down, which is the measure of the amount of water table lowered per unit of discharge, characterizes the well conditions. The specific draw down less than 1 meter per L/s is regarded as the acceptable limit. Fifteen of the tubewells tested showed a specific draw down in excess of 1 meter per L/s. To avoid huge energy losses due to excessive draw downs and increased discharge pressure, pumps should run with their control valves fully opened. This requires either matching of pump sizes to well yields or well rehabilitation.

Conclusions: Based on the results of energy audits of 64 tubewells having deep-well turbine pumps, the conclusions drawn were: The performance of majority of the tubewells was substandard as their measured overall efficiencies were below the minimum acceptable level of 50%. The low overall efficiency was mainly due to the reason that most of the motors, pumps and pipings had substandard efficiencies. The lower efficiencies were mainly due to underloading and reduced power factors. The low motor efficiencies were mainly due to underloading and reduced power effects. The low pump efficiencies were because of worn pumping components and/or improper sizing of pumps for well yields, whereas low piping efficiencies were found at situations where control valves were partially closed and/or flow meters/non-return valves were faulty. It was estimated that, if overall efficiency level of substandard tubewells identified in the study was improved to 65% (ranging from 50 to 70%) by taking appropriate retrofit/repair measures, total energy savings of about 4.8 million kWh in the current estimated energy usage of 12 million kWh per year valued at more than Rs. 7 million (@ 21 pumping hours per day and Rs. 1.50 per kWh) could be realized.

REFERENCES

ENERCON. 1989. Tubewell Energy Audit Manual (ENERCON-89-131). National Energy Conservation Centre (ENERCON). Planning and Development Division, Government of Pakistan, Islamabad.

ENERCON, 1990. CDA Tubewell Energy Audit Report (ENERCON-90-157). National Energy Conservation Centre (ENERCON), Planning and Development Division, Government of Pakistan, Islamabad.