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CORROSION IN VERTICAL TURBINE PUMPS

BY

T. E. LARSON

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CORROSION IN VERTICAL TURBINE PUMPS

By T. E. LARSON
Chemist
STATE WATER SURVEY DIVISION
URBANA, ILL.

APPROXIMATELY 360 million gallons of water are pumped per day from some 3000 wells for about 1300 municipalities and industries in Illinois. A high proportion of these wells are equipped with turbine pumps. Within a 25 mile radius of Chicago there are about 500 municipal and industrial turbine pumps supplying approximately 85 mgd. Some 275 of these turbine pumps supply approximately 70 mgd. from wells penetrating the deep sandstones.

With non-pumping water levels receding in these wells as rapidly as 8 feet and in some cases 20 feet per year, it is not surprising to find that pump settings for these 275 pumps range as follows:

Per Cent	Feet
10	200 or less
30	201—300
30	301—400
25	401—500
5	501—600

The capacities of these pumps range from 50 to 2,000 gal. per min.

By virtue of these settings the cost of pulling these pumps and the cost of replacing column pipe, shaft, and shaft tube is an item that can often amount to $6,000 per replacement. A little added cost for initial pipe protection can multiply the life of this portion of the installation several fold.

Effect of Water Level Recession

The observed water level recession in these wells will necessarily result in lower settings for nearly all pumps in the near future. Conservation will slow up the rate of recession, but nothing can avert the *eventual* approach to one or more of the following alternatives.

The Author

1. Lower pump settings limited by the efficiency of pumps for the present well bore diameters and relative economics of water from another source.

2. Use of surface water, lake or treated river water.

3. Recharge of water-bearing strata using cold water for recharge and withdrawing same in summer. This would of necessity be a cooperative measure, and the feasibility may be open to serious question.

4. Use of warm, salty water from greater depths for limited specific purposes.

Extreme conservation methods would force prospective and some established industries to resort to

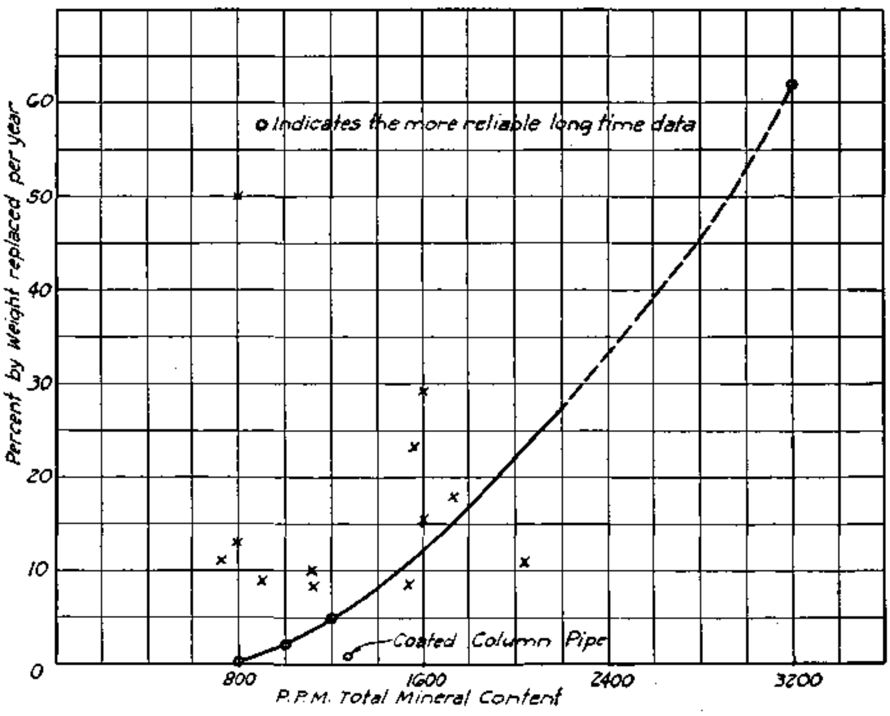
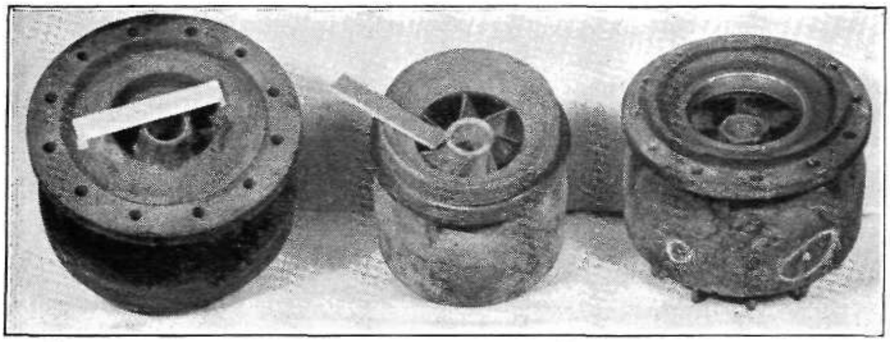


Fig. 1. Replacement of Pumps Plotted Against Mineral Content of Water



Examples of Corrosion in Vertical Turbine Pumps

(Left)

Flanged 12 in. all cast iron bowl. Diameter at impeller ring 4% in. (originally 4% in.) after 9 months' operation. Capacity reduced from 700 gpm. to 300 gpm. Also note corrosion at high pressure side of guide vanes and of cast iron bearing support. Water contained 1000-1500 ppm. mineral content and a high CO_2 content.

(Center)

Threaded 9 in. enameled cast iron bowl. Graphitization indicated on impeller seat and on exposed cast iron bearing support. Extent of corrosion in 13 months indicated by shadow below straight-edge. Stray currents were also recorded at this well where water of 1100 ppm. mineral content was used.

(Right)

Flanged 12 in. cast iron bowl with wear ring. After 14 years' service, two holes noted on bowl and much graphitization was evident on all cast iron exposed to water of 400 ppm. mineral content but considerable gas content.

one of the last three alternatives. Since the best definition of "Conservation" is "intelligent use" it would appear that the water users in a critical area should organize and promote their own conservation methods, exchange data and information and utilize the available but not generally well-known factual data and methods for "intelligent use."

At many of these installations the quality of the water is such that corrosion can be expected. Although as a general rule water quality does not play a serious role unless the mineralization is greater than 700 ppm., it is not unusual to find that waters of 2000 to 3000 ppm. mineral content are used.

At the present time it is a rarity to find a pump removed from a well in this vicinity that has not been subject to corrosion to some extent.

A recent inspection of 11 deep well turbine units abandoned by the C. M. & St. P. & P. R. R. showed that 7 of these had been abandoned due to corrosion, two due to sand erosion, one due to obsolescence. One was apparently as good as new. These pumps had been removed from wells geographically distributed over the midwest. This would indicate that the pump corrosion problem is not local.

PUMP CORROSION

In order that some confusion be removed from the question of corrosion of pumps, it is desirable to distinguish and recognize some four different types of attack. These four types are distinct and separate from mechanical erosion.

Galvanic Action

Galvanic action is recognized by the concentrated corrosion of one metal in contact with and in close proximity to another. An excellent example is the pitting that takes place on the exposed common steel shaft between two bronze impellers. A knowledge of the metals and alloys used in the construction of the pump is helpful in determining whether galvanic action could take place or not and therefore constitute a possible cause for the observed attack.

The rate of galvanic attack is in proportion to the relative exposed area of the cathodic metal to the exposed anodic area. It is also in proportion to the conductivity of the water which in turn is dependent on the total mineral content of the water.

The curve in Fig. 1 indicates the effect of water quality on galvanic action and also on general corrosion as may result from contact of mineralized water with *any* piece of steel or cast iron. Since the original publication of this curve *(JAWWA* 36, 886, 1944) nearly all of the points greatly distant from the curve have been explained by stray currents or by a high gas content.

One effect of dissolved oxygen is to decrease polarization or to increase the potential difference or the force driving galvanic current from the anode to the cathode. In other cases particularly with some hard waters it is recognized that dissolved oxygen can help to reduce corrosion by assisting in maintaining a calcium carbonate and iron oxide film or coating.

Increasing the relative velocity between the water and the metal by increasing the motor speed is generally believed to cause an increase in the corrosion rate. It is again recognized that under specific conditions of protective action (polarization) the reverse condition may exist. It has often been demonstrated that an idle pump corrodes faster than one in use. The use of bronze bowls with bronze impellers eliminates the possibility of galvanic action between impellers and bowls.

Galvanic action can also be enhanced by a situation where two galvanic cells are set up in series in the installation. Such a situation exists where bronze impellers are used with cast iron bowls and at the same time copper-alloy bearing-retainers are used with a water lubricated steel shaft or in the instance of oil lubricated pumps where bronze impellers are used with cast iron bowls and water is permitted to enter the inclosure tube above the bowls and in contact with the bronze bearings and steel shaft.

It is obvious in these cases that current will flow from the iron impeller seats through the water to the bronze impellers and up the shaft to the bearings where it will leave the shaft through the water to the bearing retainers or to the bearings and down the column pipe or the inclosure tube to the bowls—a vicious cycle. It would be difficult to reverse one of the cells to exactly counteract the other and without inaugurating a concentrated attack at another point.

There is considerable room for argument when any discussion on galvanic action takes place. Although the fundamental theories have been fairly well developed, the practical application of these theories is often obscure and requires considerable experimentation on the actual finished product.

Water Line Corrosion

Water line corrosion is also common and due to the existence of what is commonly called the oxygen concentration cell. It is adequately described in many textbooks. The obvious simple remedy is paint or some other good protective coating.

Carbon Dioxide Corrosion

Carbon dioxide corrosion is that which takes place at the high pressure points in the pump bowls and inside the column pipe and outside the shaft tube. Cavitation is distinguished from this corrosion by the fact that it takes place at the low pressure points on the impellers. This carbon dioxide corrosion is recognized by the occurrence of noticeable pitting at certain points on the guide vanes in the bowls and in the column pipe and on the shaft tube particularly just above the bowls and to a lesser extent just above the spiders.

It may be suggested that this is caused by the release of gas bubbles in the water at low pressure points on the underside of the impellers and possibly at the entrance to the suction pipe. This can happen particularly if rough edges are present. These gas bubbles are composed of nitrogen, water vapor and carbon dioxide and can be expected to form in any water normally present in the ground under artesian pressure. These gas bubbles pass through the turbine unit and column pipe and undergo various changes in volume due to the changes in pressure that take place and are mechanically carried through the pump and into the column pipe.

On rapid increase in pressure the bubbles exist in the water with carbon dioxide gas at a high solution potential and as the carbon dioxide dissolves, the water film on the surface of each bubble is excessively acid due to the formation of carbonic acid. As the gas bubble with its acidic surface film passes over metal, corrosive action takes place due to the carbonic acid. This type of corrosion has been recognized at the high pressure points on the vanes in the bowls, at points inside the column pipe located from 6 in. to 2 ft. above the top of the bowls and at points located several inches above the spiders between the pump shaft or shaft tube and the column pipe. The extent to which this corrosion is noted above the spiders decreases with increased distance above the pump bowls. This decrease is due to the fact that as the water moves up the column pipe, the carbon dioxide pressure within the bubbles decreases and the relative amount of corrosion decreases accordingly.

This theory also explains, in part, the reason for the more prevalent corrosion reported in the Chicago area at the present time than that formerly experienced. This is due to the fact that the static and dynamic head on the waters as they exist in the sandstones is less now than formerly and, therefore, the tendency for bubble formation is greater than before. An increased tendency for bubble formation in present installations can perhaps also be explained by the fact that greater capacity pumping units are now used, creating a greater pressure drop at the suction end of the pump. These greater capacity units are not always accompanied by proper increase in column pipe or suction pipe.

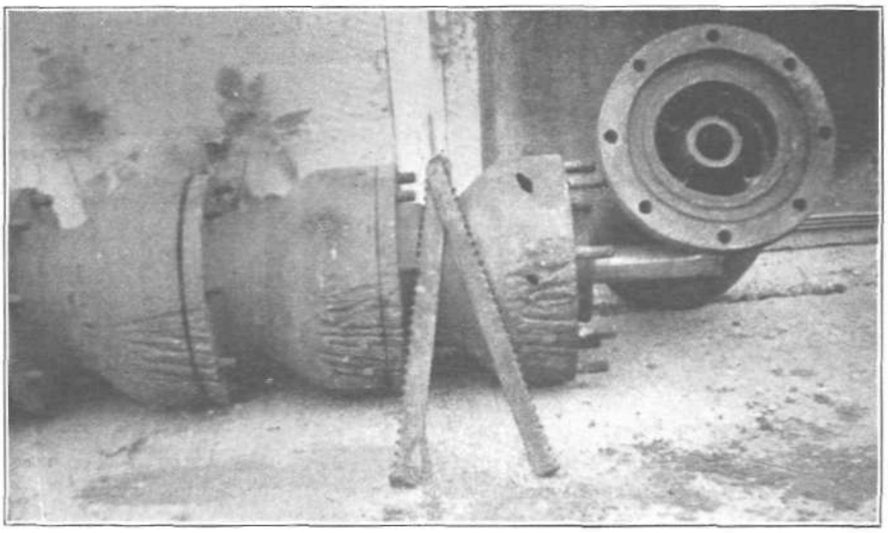
The same type of corrosion takes place at shallow settings where water of high carbon dioxide content is handled. The presence of hydrogen sulfide also increases the corrosion tendency. A "worm-eaten" shaft or shaft tube is also due to this phenomenon.

Stray Currents—a Question

Stray currents have been accused of causing corrosion in many cases where no other reason is evident. Perhaps this is justified and perhaps not. No thorough study has been made on this factor in pump corrosion and it is questionable whether completely satisfactory field data can ever be obtained. Some indications can, however, be obtained by measurements of possible current flow with a milli-voltmeter between the discharge line and the pump head and between the column pipe and the well casing. If the potential difference is irregular it is assumed that the cause is not due to galvanic potentials but to stray currents. Any further interpretation must for the present be only theoretical and must recognize the fact that electric current takes the path of least resistance to complete its circuit or to pass from a point of high potential to one of lower potential.

Stray currents have been observed and are known to exist at many installations. It is generally a simple matter to connect a milli-voltmeter across a disconnected discharge line or from the pump head to the well casing. To what extent they may be damaging to the pump will depend on whether the polarity is such as to enhance or inhibit galvanic action. Inhibition is included since cathodic protection is actually the application of a controlled "stray" current. As to the source of stray currents, (1) they may be transmitted from grounded lines through the distribution pipe line to the pump or (2) they may be transmitted through the earth structure to the well and pump from electrified railways or other grounded electrical power equipment.

A series of tests for possible stray currents have been made at 32 wells in Illinois. It was significant to note that the well casing was negative to the discharge pipe line or to the column pipe in 18 out of 19 cases where such potential could be measured. At about 50 per cent of the wells a varying potential difference was noted to be present between the discharge line and pump head or between the pump head and the well casing. These tests of course tell little about ground



A Combination of Galvanic and CO_2 Attack

The effect of galvanic action is visible on the exterior of this 7-stage 10 in. C.I, well pump which had been in contact with a brass well screen for about 5 years. The two tooth-edged strips are remnants of the brass strainer. Through the walls of the bottom bowl of the pump are two holes resulting from CO_2 corrosion. The water had a mineral content of about 500 ppm., alkalinity of 400 ppm., and a high methane and carbon dioxide content.

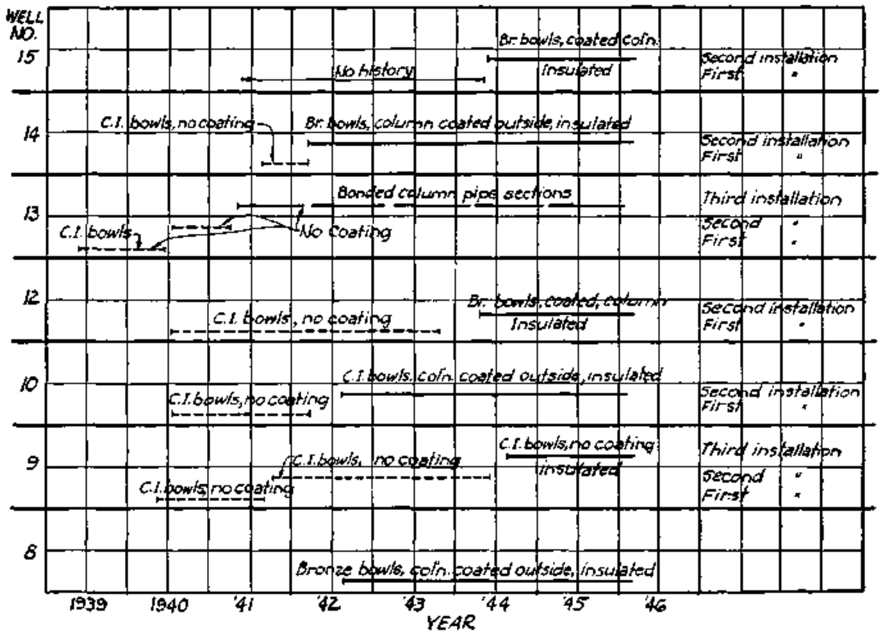


Fig. 2. Pump History

The length of life is indicated by the length of the line.

currents which may exist under ground from one depth to another.

Alternating Current

Thus far discussion has referred to direct current. Alternating current should not be overlooked since it is entirely possible for alternating current to be rectified to give a pulsating direct current. In one instance, an A.C. potential (but no D.C.) was observed between the power cable conduit and the pump head. Excessive corrosion was also noted at this installation. A duplicate installation had little corrosion where the cable conduit had been left off the cable and therefore no metallic contact was present.

Stray A.C. shaft currents have been noted to cause corrosion at bearings in industrial motors and generators. A.C. currents have also been proven to be corrosive to underground lead cable sheaths.

If stray currents are the cause of deterioration it should perhaps be emphasized that it is futile to experiment on the choice of metals to prevent repeated corrosion damage.

PUMP CORROSION PREVENTION

Prevention of corrosion will depend largely on the type of installation, the corrosion encountered and the economics involved. It is recognized that galvanic corrosion can be reduced by the use of all bronze bowls with bronze impellers and stainless steel impeller shaft. The additional cost over a similar installation with CI bowls, bronze impellers and stainless steel shaft is in the neighborhood of 80 per cent for the turbine unit but often only about 10-20 per cent of the total cost of the installation. Over a 5-year period a decided net savings should be effected (1) in power costs by a *maintained* efficiency, (2) by the elimination of the replacements and (3) by elimination of the costly necessity for pulling the pump.

A protected column pipe and shaft tube is almost a necessity for any deep setting. Hot-spun bitumastic (Plastex) Natasco and other coatings have proven effective. A problem still exists where wrench marks have damaged the coating on the shaft tube. Painting these fractures on the spot is the least that can be done to'repair such damage and prevent accelerated attack at these points. Here again the cost of prevention is a minor fraction of the savings.

Column pipe protection can be obtained at an added cost of 5 to 50 per cent of the cost of the pipe itself. With regard to protective coatings in general, it is first essential that the metal surface be clean and dry before the application of any coating. It is also recognized that in general the more difficult corrosive conditions require more costly protective measures. The question of "How costly must the coating be to be effective" will best be answered by experience and correlation of cooperative data. The following protective coatings are among the **more** commonly used and have varying protective values as well as varying costs.

1. Baked-on resins.
2. Resin-base paints.
3. Chlorinated rubber.
4. Rubber-base paints.
5. Asphalt and coal tar-base paints.
6. Lead base and lead-chromate base oil paints.

It should be emphasized that an expensive coating will be of no more value than a cheap coating if the pipe is not clean and dry during the application.

Several cathodic protection installations have been made in Illinois. These have involved the use of an auxiliary electrode at the suction pipe and forcing a small current through it and using the whole pump unit as a cathode for the return of current to the surface where it is tapped off the pump head, the head shaft and in some cases off the well casing. A special arrangement is provided to make the lower end of the impeller shaft and the bowls of equal potential. These installations have not been in use sufficiently long to judge their economic value.

The insertion of insulation between the discharge line and the pump head is being used to inhibit or prevent stray current electrolyses. In some installations the well casing is also insulated from the pump head and column pipe. Where such protective measures are installed it is imperative that the housing for the power cables and the return water lines for water lubricated pumps should also be insulated from the pump head or the efforts will be nullified.

Fig. 2 shows the history of pump replacements in seven wells used by an industry whose property is overrun by stray currents from their operating machinery.

At the present time there is no standardization among manufacturers on specifications for materials for corrosion prevention under various conditions. This is due to the absence of any complete set of unbiased comparative data on the economics of repair and maintenance and to the lack of laboratory studies on the prevalence of galvanic currents within the units.

Pump manufacturers and owners could satisfactorily obtain comparative data on the value of prevention methods by conducting standard tests for efficiency periodically on actual installations from the date of installation to the. time of removal. These tests could be made on each of a series of pumps of known construction and known operating conditions and the pumps could be singularly equipped with and without the various protective methods against corrosion.

A thorough and critical inspection should be made on each after removing for comparison. Such data at the end of a five or ten year period would then be available for (1) standardization purposes, (2) for comparison from the standpoint of economic operation . *and* economic maintenance and (3) for publication for reference purposes. Nothing will speak to the plant engineers more effectively than "dollars and cents" figures obtained from actual field installations.

There are other methods of attack available to the engineers in the pump industry. Laboratory tests should disclose much factual data on the prevention of the corrosive damage experienced in pumps. There is room for an appreciable amount of theoretical and practical "engineering" on the subject of galvanic and stray current corrosion.

Acid Treatment

With regard to efficiency of operation; many pumps have been inspected which were coated or even filled with an accumulation of iron oxide in the bowls and sometimes in the impellers. In one installation a deposit of calcium carbonate of one-half inch thickness was! present in the discharge pipe. The sources of such deposits are questionable. There is good evidence that a large portion of the iron deposits are due to an accumulation of corrosion product from the bowls. These bowls appear to retain their original shape but careful inspection will nearly always show the cast iron surface to be softened or graphitic.

A deposit of this type naturally reduces efficiency of operation and for deep settings it is costly to remove by pulling the pump. It is entirely feasible to clean such deposits and increase the efficiency of operation by treating these pumps *in place* with inhibited hydrochloric acid.

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