SUCTION FLOW CONTROL DEVICE

INTRODUCTION

It has been discovered that changing the pump energy distribution to a well can change the hydraulic flow characteristics observed for both the well and the surrounding aquifer. As early as 1898, it was recognized that Darcy's Law (linear flow) did not properly describe the hydraulic flow field around a well bore. In large capacity wells, the pump energy forces the entry of water to occur in or near turbulent flow opposite the end of the suction pipe or point of energy release by the casing to the screen or formation below.

Sand control to a well can be achieved by reducing the velocity at the critical points opposite the pump suction or the entry of energy to the formation or well screen and reduce flow to laminar conditions. In laminar flow there would be no inertial forces to physically move the sand particles thus they would remain in place in the formation. For a device like Lamnaflo (Aquastream), a type of suction flow control device (S.F.C.D.) to work, it must shift the energy distribution of the pump to distribute the flow over a larger column height of well bore or screen thus decreasing the overall velocity of flow to transitional or laminar conditions.

THEORY OF OPERATION

To develop the basic theory of operation of suction flow control devices, one first must refer to the law of conservation stated by Darcy that the flow rate through the aquifer is the product of the formation permeability times the cross sectional flow area times the hydraulic gradient. Formation permeability is the velocity at unity hydraulic gradient through porous material which is the approximate limit of laminar flow through the formation for the existing temperature and fluid viscosity present. For a given area of flow, the velocity then decreases linearly in proportion to the driving force or hydraulic gradient.

When the velocity is no longer directly proportional to the driving head, it becomes turbulent in which the square of the velocity is proportional to the driving force. There is a transition between laminar and turbulent flow in which neither condition is mathematically defined called transitional flow.

To better define the flow field around the well, the basic hydraulic flow equation where the fluid flow in any system is a product of a velocity, times a cross sectional area applied to a well. Thus, if the cross sectional area is the cylindrical area of the bore hole wall, defined by the length of screen in the vertical dimension and the circumference expressed in terms of the diameter of the well bore in inches, then the flow to that well would be the product of permeability, times the length of the screen, times the diameter. From field experience, it has been determined that turbulent flow in a well bore begins at 2.35 times the laminar flow limit, and the normal limit of turbulent flow available through a formation is approximately 12 times the laminar flow rate.

These equations assume uniform vertical distribution of flow through the cylindrical wall area for the entire depth or thickness of the formation of uniform permeability.

The following figures illustrate the basic flow distribution that occurs normally in a large capacity well.

In figure 1 with the pump set above the well screen, the energy is transmitted by the casing to the top of the screen and then flow enters the top of the screen in turbulent flow and is pushed downward by the formation permeability in turbulent flow until the energy is dissipated. The energy may be dissipated before the bottom of the well is reached in which case no water enters the bottom of the well regardless of the formation permeability or depth of the well. If the energy is not dissipated before the bottom of the well is reached, then the energy will move further out into the formation developing a greater level of turbulent flow at a greater distance from the well.

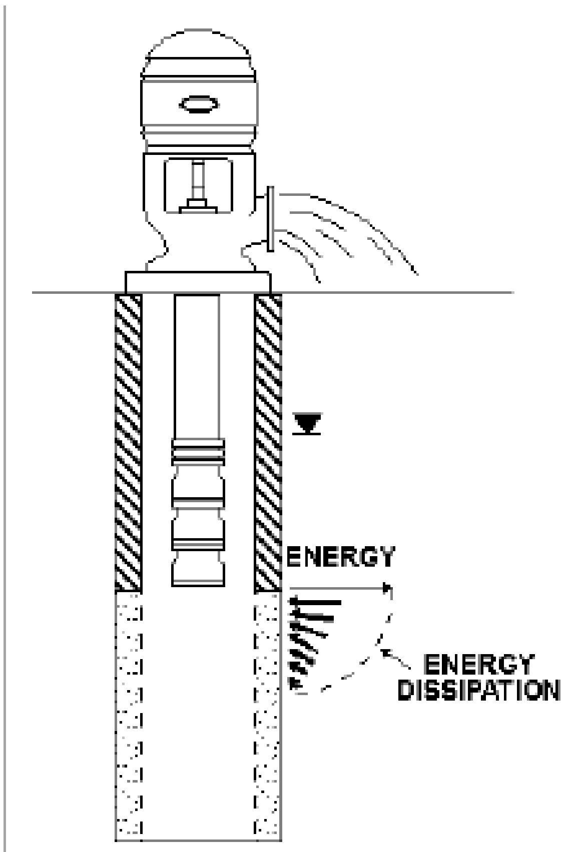

Figure 1, Pump Suction Above Well Screen

In Figure 2 is a theoretical operation of the Lamnaflo (Aquastream), a suction flow control device. The original Lamnaflo (Aquastream) device consisted of concentric cylinders filled with a granular media of varying size and varying slot sizes to distribute the energy uniformly from the pump suction through the vertical cross section of the well. Subsequent modifications have been made to change the physical configuration of the suction flow control device with an inner tube slotted with various spacings for energy distribution and then coated with a reinforced silica sand or gravel layer with an epoxy compound of varying particles sizes, to further limit the entry of sand and change the energy distribution.

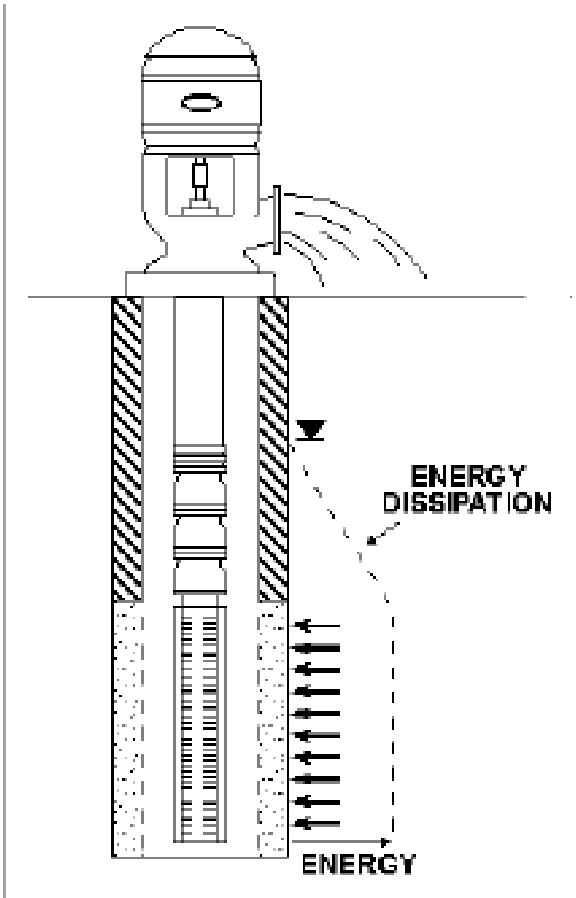

Figure 3, Pump with Suction Flow Control Device

It has been found that it is not necessary to shift turbulent flow to transitional or laminar flow to stop sand pumping. Sometimes it is only necessary to shift the flow to a different zone in the formation of slightly better permeability thus reducing the flow velocity and sand production from the previous zone. Benefits have been observed for screen intervals as short as 10 feet. Normally the benefits are greater with longer screen intervals.

Sand control may be achieved by shifting the velocity to a more stable portion of the formation without a significant increase in well specific capacity. In many cases however there is a significant increase in well specific capacity due to the shift of the energy velocity allowing transitional or laminar flow to occur in the formation. The maximum increase in specific capacity that can be achieved is approximately 2.35 times the natural developed specific capacity for an efficient well. Sometimes a partial increase in specific capacity is achieved that is allowable by the formation permeability and length of screen installed during the original construction of a well.
The primary control of water yield from a well is regulated by the formation permeability available around the well bore and the thickness of formation penetrated by the well screen or formation. If the well formation permeability has deteriorated due to biofouling, mechanical or chemical plugging, then the suction flow control device cannot operate properly.

CASE HISTORIES

Madison, Indiana utility system had two 5 year old sand and gravel wells in the Ohio River Valley that pumped excessive sand and had to be shut down. An Aquastream SFCD was installed inside of a 16 inch diameter screen, 30 feet in length in a well 138 ft. depth with this unit attached to the suction nozzle of a vertical turbine pump. It was a complete success from the start and four years later continues to produce more than 1,000 gpm of sand free water at a better specific capacity than originally developed from the well.

Ft. Bend County, Texas W C & I D No. 2 had well. No. 3 with 220 feet of 10 inch diameter screen in intervals spread through the bottom 800 feet of a 1,600 ft. deep well. The well pumped more than 2,500 ppm of sand at 800 gpm and was used for stand by service only. Aquastream units 6 inches ID by 8.25 inches OD were set-inside the screen intervals properly spaced and sealed to the upper 16 inch casing by a packer seal serving as a liner. After installation of the SFCD the well produced 1,350 gpm with a measured sand content of 0.1 ppm with a 30% improvement in well specific capacity.

In Wisconsin, a 400 feet deep sandstone open hole well produced excessive sand with pumped water. An eight element 6 inch ID by 8.25 inch OD Aquastream SFCD was installed attached to a shroud surrounding a submersible pump. The result was complete control of sand (no sand production) with an improvement in well yield.

CONCLUSIONS

The hydraulic flow to vertical wells is much more involved than previously realized. The point of energy release to a well can greatly influence the performance of the well in terms of yield or specific capacity and production of sand. Most high-capacity wells operate in the turbulent flow zone, thereby invalidating Darcy's Laminar flow conditions in the formation around the well bore.

To advance the knowledge of well hydraulics and to develop the appropriate mathematical relationships, it is necessary to redefine the field coefficient of permeability as the limit of laminar flow through porous media for the existing fluid viscosity and temperature existing in the formation. Hydraulic conductivity should then be defined as the field coefficient of permeability corrected to a standard fluid viscosity and temperature.

It has been learned that for best performance from a well and to provide a more uniform flow through the vertical height of the well screen, the energy of the pump should be distributed proportionally through the full depth of the well screen or open borehole. Flow from the aquifer to the well bore or screen is a function of the formation permeability, flow area, and energy distribution of the pumping system.

It has been learned that the fluid flow velocity for the aquifer or formation will naturally enter the well bore at the beginning of turbulent flow opposite the point of energy release. The energy will dissipate upward, if possible, to the effective pumping water level or be forced downward by the permeability of the formation until dissipated. In a deep well when the pump energy is dissipated, essentially no further flow enters the well, below the point of energy dissipation regardless of the formation permeability or depth of the well. The same principle applies equally to a horizontal slotted pipe or laterals in a collector well.