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Project Summary

Methods for Determining the Mechanical Integrity of Class II Injection Wells

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The Underground Injection Control (UIC) program regulations require injection well operators to test the mechanical integrity of injection wells on a periodic basis. The testing is to ensure that there is no significant leak in the casing, tubing or packer, and that there is no significant fluid movement through vertical channels adjacent to the injection well.

There are a number of methods available for mechanical integrity testing. These include monitoring of annulus pressure, pressure testing, temperature logging, noise logging, pipe analysis surveys, electromagnetic thickness surveys, caliper logging, borehole television, borehole televiewer, flowmeter surveys, radioactive tracer surveys and cement and cement bond logging. Only temperature logging, noise logging and radioactive tracer surveys can be utilized to provide relatively definitive information regarding the presence or absence of fluid movement behind casing; cement bond logs provide information from which fluid movement may be inferred. With the exception of cement bond logging, all of the testing methods can be used to locate leaks in casing.

The full report describes each of the methods that can be used in mechanical integrity testing, including the principles, equipment, procedures, interpretation, cost, advantages and disadvantages and examples of each technique. Other methods which may also have application in mechanical integrity testing, but which require additional field testing to establish their effectiveness, are also described.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Public Law 93-523, the Safe Drinking Water Act, requires the U.S. Environmental Protection Agency to develop minimum requirements to assist in the establishment of effective state programs to protect underground sources of drinking water from contamination resulting from the subsurface emplacement of fluids through well injection.

Inherent in a process for protecting underground sources of drinking water is the determination of the mechanical integrity of the injection well. An injection well is determined to have mechanical integrity when it meets both of the following criteria: 1) there is no significant leak in the casing, tubing or packer; and 2) there is no significant fluid movement into an undergound source of drinking water through vertical channels adjacent to the injection well.

The full report is intended to provide a concise description of methods or technologies which are currently being used or which may have application in determining the mechanical integrity of an injection well.

Procedure

In developing the full report, past, present and potentially available methods for determining the mechanical integrity of injection wells were researched Government officials in oil and gas producing states were surveyed regarding regulations, requirements, methods and procedures used to determine mechanical integrity of injection wells. Efforts were made to document the applicability of many types of services provided by well logging companies. Attempts were also made to assess the applicability of many types of equipment for determining the mechanical integrity of injection wells and to identify the availability of companies able to perform mechanical integrity services

Results

A review of the available literature revealed that a significant amount of information has been written abcut the testing of wells of downhole problems such as leaks in the casing or flow behind the casing. However, most of the work described in the literature has involved the testing and inspection of producing oil and gas wells rather than injection wells. Fortunately, most of this technology is also applicable to injection wells.

In general, two types of injection wells are used in oil and gas production operations 1) brine disposal wells in which the fluid is injected into a receiving formation for the purpose of retention; and 2) enhanced recovery wells in which the fluid is injected into a producing formation for the purpose of increasing the production of oil or gas.

Injection wells can be operated without endangering ground water provided they are properly constructed and maintained in such a way as to ensure their mechanical integrity. Salt water injected under pressure or by gravity into wells may escape through leaks in the well casing caused by a mechanical failure within the well, or through migration of brine forced up between the well's outer casing and the wellbore because of a faulty cementing job. Determination of the mechanical integrity of an injection well is extremely important, since it provides a measure of the protection of underground sources of drinking water from contamination.

Conclusions

The Underground Injection Control (UIC) program requires that the absence of a significant leak in the casing, tubing or packer be evaluated using either monitoring or annulus pressure, pressure testing with liquid or gas or, in specified instances, monitoring records that show no significant change in the relationship between injection pressure and injection flow rate. The absence of significant fluid movement can be evaluated by using the results of a temperature or noise log, or, by presenting well records that demonstrate the presence of adequate cement to prevent migration.

There are a number of other methods which are not currently approved for use which may be used to determine the mechanical integrity of injection wells. Pipe analysis surveys, electromagnetic thickness surveys, caliper logging, flowmeter surveys, radioactive tracer surveys and cement bond logs, which are available from professional well logging companies, are capable of detecting leaks in the casing, tubing or packer and/or fluid movement behind casing. Borehole television and borehole televiewer surveys, which are performed by specialized contractors, may also be used to detect leaks. Table 1 provides a detailed listing of the detection capabilities, well diameter constraints and pressure/temperature limitations of each of these techniques as well as the techniques approved for use in the UIC program.

The advantages and disadvantages of each method must be understood to facilitate a rational decision regarding which method or methods can be applied in each individual situation. Few of the methods which can be employed to test the mechanical integrity of injection wells can be used alone to provide definitive information on both the presence and the location of leaks in the casing, tubing, or packer, and fluid movement behind the casing. In general, it will take two or more testing techniques, run either independently or in conjunction, to ensure that no significant leaks exist in the casing and that no fluid movement is occurring in the cement sheath behind the casing. Table 2 provides a detailed summary of the advantages and disadvantages of all methods which may be used to determine the mechanical integrity of injection wells.

Recommendations

There are many methods that may be applicable for determining the mechanical integrity of injection wells. Because of the many variations in injection well completions, it is not possible to make recommendations regarding mechanical integrity testing methods that apply to all such wells. Since each is unique, testing procedures should be carefully selected and tailored to the individual well. The following list of criteria should be used to help establish a systematic approach to choosing the appropriate testing methods:

1) Determine the type of completion of the well;
2) In wells completed with tubing and packer, determine the type of packer to evaluate the maximum amount of pressure which can be applied to the annulus between the tubing and casing;
3) Determine the inside diameter of the casing or tubing to assess tool diameter limitations;
4) Determine the depth of the well to evaluate the pressure/temperature limitations;
5) Determine the wall thickness of casing or tubing since selected methods rely on the measurement of thickness to determine the soundness of the pipe;
6) Attempt to determine the interval(s) of injection to facilitate the application or interpretation of tests;
7) Evaluate the availability of professional companies to perform the service, if applicable; and

Table 1 *Summary of Applications of Methods Which May be Used to Determine the Mechanical Integrity of Class II Injection Wells*

	Detection Capability		Well Diameter Constraints		For Use in Casing or Tubing	Pressure/Temperature Limitations of Technique
	Leaks in Casing Tubing or Packer	Fluid Movement Behind Casing	Minimum	Maximum		
Monitoring Annulus Pressure	X		N/A	N/A	**	N/A
Pressure Testing	X		N/A	N/A	both	N/A
Temperature Logging						
(Gradient)	X	X	1½"	8½"	both	20 000 psi/400°F
(Differential)	X	X	1½"	8½"	both	20,000 psi/400°F
(Radial Differential)	X	X	2⅜"	13⅜"	both	20 000 psi/400°F
Noise Logging	X	X	1½"	no limit	both	15,000 to 22,000 psi/350°F
Pipe Analysis Survey	X		4½"	9⅝"	casing	10,000 psi/250°F
Electromagnetic Thickness Survey	X		4½"	9⅝"	casing	20,000 psi/350°F
Mechanical Caliper Logging	X		2"	13⅜"	both	10,000 psi/300°F
Borehole Television	X		3"	36"	casing	5,000 psi/175°F
Borehole Televiewer	X		2⅛"	8½"	casing	15,000 psi/175°F
Flowmeter Surveys	X		2"	10"	both	varies widely according to tool design
Radioactive Tracer Surveys	X	X	1½"	no limit	both	15,000 psi/300°F†
Cement Bond Logging		*	2"	no limit	casing	20,000 psi/400°F

*Inferred only
**Annulus between casing and tubing
N/A not applicable
†Depends on choice of gamma ray detector

8) Evaluate the cost of the method with respect to the type of results desired.

Further study is needed in the following areas:

1) Gamma ray logging has traditionally been used in injection wells for purposes other than leak detection, however further study into the applicability for leak detection is needed;
2) Helium leak testing has been used to test for leaks in other applications but has not been applied specifically to injection wells. This method should be laboratory and field tested to determine its applicability to injection wells;
3) Volumetric scanning has been used for fracture evaluation in open boreholes. Further evaluation for use in cased hole applications is needed; and
4) Continuous oxygen activation logging has been field tested for application in determining leaks in injection wells but the results are inconclusive. Further testing is needed to assess the applicability of this technique.

Table 2. *Summary of Advantages and Disadvantages of Methods That May Be Used to Determine the Mechanical Integrity of Class II Injection Wells*

Method	Advantages	Disadvantages
Monitoring Annulus Pressure	Provides "real time" measurement	Injected fluid temperature and pressure changes complicate interpretation
	Well does not have to be taken out of service	Provides no information on leak location
	No specialized equipment needed	Limited to use in wells completed with tubing and packer
	Very inexpensive	
	Provides either continuous or frequent, regular measurement	
Pressure Testing	Most tests of short duration	Some disruption of service
	Minimum of specialized equipment needed	Non-staged tests provide no information on leak location
	Relatively inexpensive for most wells	Application of excessive pressures could damage well
	Results straightforward and easy to intrepret	
	Staged tests provide information on leak location	
Temperature Logging	Can detect and locate both leaks in casing, tubing or packer and fluid movement in channels behind casing	Requires professional service, equipment and interpretation
	Gradient and differential logs available from most logging companies	Requires removal of well from service for extended period (24 to 48 hours or more)
		Use limited in large-diameter wells
		Radial differential log available from only one logging company
Noise Logging	Can detect and locate both leaks in casing, tubing or packer and fluid movement behind casing	Requires professional service, equipment and interpretation
	Possible to distinguish between single and dual phase flow	May require removal of well from service for extended period
	Possible to estimate rate and volume of flow from a source	Injection operations must be stopped during logging
	Available from most major logging companies	May not be useful for detecting flow behind casing when pressure differentials too low
Pipe Analysis Survey	Developed specifically to evaluate downhole casing damage	Offered only by a select few well logging companies
	Can distinguish between internal and external casing damage	If tubing removal necessary, requires removal of well from service for extended period
	Can detect and locate small defects (1/8-inch diameter) in casing	
Electromagnetic Thickness Survey	Offers only method of detecting defects on the outer string of double casing string	Cannot detect small casing defects (less than 1-inch diameter)
		If tubing removal necessary, requires removal of well from service for extended period
		Difficult to distinguish true cause of log anomalies
		Requires availability of baseline log against which comparison is made to subsequent logs
		Offered only by a select few well logging companies
Mechanical Caliper Logging	High resolution caliper provides very accurate record of condition of casing interior	May not detect small-diameter (1/2-inch) defects
	Log can be run in short amount of time	Difficult to locate vertical splits or cracks in casing
	Log can be run in either tubing or casing	High resolution caliper offered only by a select few well logging companies
Borehole Television	Provides for direct visual inspection of downhole conditions	Well fluid must be free of suspended material
	Video tape recording provides for ease of replay and comparison with other logs	If tubing present, must be removed
		Operation requires removal of well from service for extended period
		Service not offered by commercial well logging companies, specialized contractor necessary
		Cannot be run in high temperature/pressure environments

Table 2. *(Continued)*

Method	Advantages	Disadvantages
Borehole Televiewer	*Provides easily recognizable image of casing interior* *Provides either photographic or videotape record* *Limited interpretation necessary* *Can operate in less favorable environments than borehole television*	*If tubing present, must be removed* *Operation requires removal of well from service for extended period* *Technique relatively slow* *Service not offered by commercial well logging companies, specialized contractor necessary*
Flowmeter Surveys	*Log can be run in either tubing or casing* *Possible to estimate volume of flow from leak* *Log run during injection, little disruption of service* *Available from most major logging companies*	*Flow rates must be high enough for flowmeter to function* *Injection rate must be held constant for proper interpretation* *Requires professional service, equipment and interpretation*
Radioactive Tracer Surveys	*Log can be run in either tubing or casing* *Log run during injection, little disruption of service* *Available from most major logging companies*	*Requires use of radioactive tracer* *Requires professional service, equipment and interpretation*
Cement Bond Logging	*Infers presence of channels behind casing* *Available from most major logging companies*	*If tubing present, must be removed* *Cannot be used to find leaks or determine fluid movement* *Many factors affect log validity* *Requires professional service, equipment and interpretation* *Interpretation complicated and not standardized within industry*

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The complete report, entitled "Methods for Determining the Mechanical Integrity of Class II Injection Wells," (Order No. PB 84-215 755; Cost: $23.50, subject to change) will be available only from:
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