METHODS FOR DETECTING PERFORATIONS IN CASINGS OF WELLS EXPLOITING GEOTHERMAL FLUIDS

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Key Words: Dogger aquifer, geothermal fluid, freshwater aquifer, corrosion, perforation, pollution, detection.

Abstract

The geothermal installations exploiting the Dogger aquifer in the Paris Basin experience problems of corrosion and scaling in the well casings. When localized, corrosion can lead to perforations in the casing, thereby increasing the risk of contamination by geothermal fluids of freshwater aquifers (Albian, Chalk) traversed by the wells.
To detect perforations, for which there are numerous scenarios, several different methods can be used. For this particular geothermal application, two methodologies have been adapted:
1) Analysis of samples taken at the production wellhead of the geothermal well or at the freshwater pumping station, allows us, for some chemical species, to detect a volumetric proportion (v/v) of Albian water in Dogger water of as little as 1%, and even less than 0.5% in the opposite case.
2) Remote monitoring of the different operating parameters (flowrate, pressure, temperature, etc.) allow us to determine, in some cases and almost in real time, the probability of perforation. Emergency measures can then be taken.

1. INTRODUCTION

1.1 Context

Carbon steel casings of geothermal doublets exploiting hot water from the middle Jurassic Dogger Aquifer in the Paris Basin (France) are subject to corrosion due to the agressivity of the geothermal fluid containing CI-, HCO_3^-/CO_2 and HS^-/H_2S. Because of various physico-chemical phenomena, there is more corrosion in the upper part (presence of gaz phase) of the production well, but at the present time, most of the doublets are treated against corrosion with quaternary ammonium salt inhibitors, decreasing by a magnitude of 10 to 100 the average corrosion rate, reducing it to less than 0.1 mm/year.

Producing and injection wells of low enthalpy geothermal plants often penetrate fresh water aquifers (Albian reservoir, etc.) which are used as a drinking water resource in the Paris region. The two wells may be completely or partially equipped with dual casing. Following localized or prolonged corrosion of the internal casing by the geothermal fluid, the casing may be pierced. Depending on the existence or absence of dual completion in the area of the perforation, the geothermal fluid may enter into the water from the adjacent aquifer, thus creating the risk of pollution of the water.

1.2 Objective

The aims of this work are an establishment of a general methodology for the detection and assessment of perforations in well casings in order:
- to avoid pollution by geothermal waters (treated by inhibitor or not) of shallow ground water used for drinking water supplies. In addition to pollution, this might cause a reduction in the flow rate of the production well at the surface,
- to avoid the intrusion of fresh water through the geothermal casing, which would lead to cooling of the geothermal water in the production well or to an increase in injection pressure at the injection well; both cases lead to a decrease of the energy yield.

1.3 Types of perforations

Let us take now the example of a working geothermal plant where a casing perforation may have occured. Hence the following questions: How is the perforation detected ? In what direction will the water migrate ? This paper tries to provide an answer to the first of these questions, while considering the different types of perforations and of possible geothermal or fresh water migration.

Type I (Inflows): Water entering the casing from the outside.
This type of leak is revealed when the pressure in the casing is lower than that of the surrounding rock. It normally occurs with high geothermal water production flowrates and usually at the aquifer level (fig. 1).

Type O (Outflows): Water leaking from casing to the outside
This occurs when the pressure in the casing is higher than that of the surrounding aquifer. It normally occurs with low geothermal water production flowrates. The rate of leakage depends on the type of the surrounding rock (fig. 1 & 2).

Type H (Hole): Perforation in one of the walls of a double casing with no direct flow to the outside
This usually occurs in the case of general corrosion in the upper part of the casing. Double casing is a technique used for exploitation of the Dogger aquifer in the Paris Basin in order to protect freshwater aquifers in the case of perforation. The Double casing generally extends 200-300 m below surface, and, for certain production wells it extends from the lower level of the pumping chamber down to the Albian aquifer (–1 100 m). Double casing is common between the surface and the Albian aquifer for injection wells (fig. 2).

Type I + O: Change of flow direction depending on rate of leak
This occurs when pressure in the casing varies according to flow because of variations induced by the head losses. Perforations occur mainly in the upper part of the casing. The surrounding rock is either an aquifer or capable of absorbing and then returning the water (fig. 1).

Type I - O: Water enters at one level and exits at another level and **Type O - I: Water exits at one level and enters at another level.**
These two situations mean that there are at least two perforations located at different levels (fig. 1 & 2).

2. CHARACTERISTICS OF WATERS COMING FROM DIFFERENT AQUIFERS

2.1 Characteristics of fresh water aquifers

These waters are provided by aquifers situated between the Dogger of the Pans Basin and the surface These aquifers, particularly the Albian, make up the principal dnnking water reserves of the Pans region Chemical analysis of the species dissolved in the water shows that, apart from very rare cases, the water complies with the drinking water standards established by the European Community (Abou Akar, 1994) The source of the analyses is the French "*Observatoire National de la Qualité* der *Eaux Souterraines* (ONQUES)"

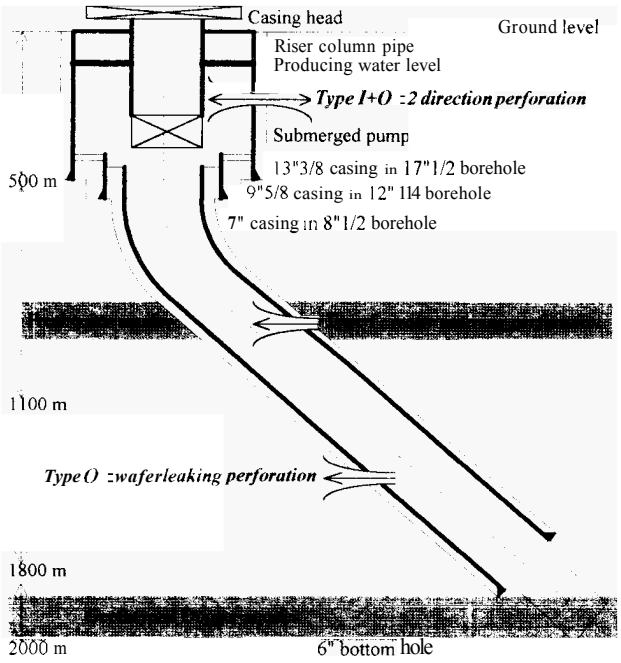

Figure 1 - Location of perforations in the production well

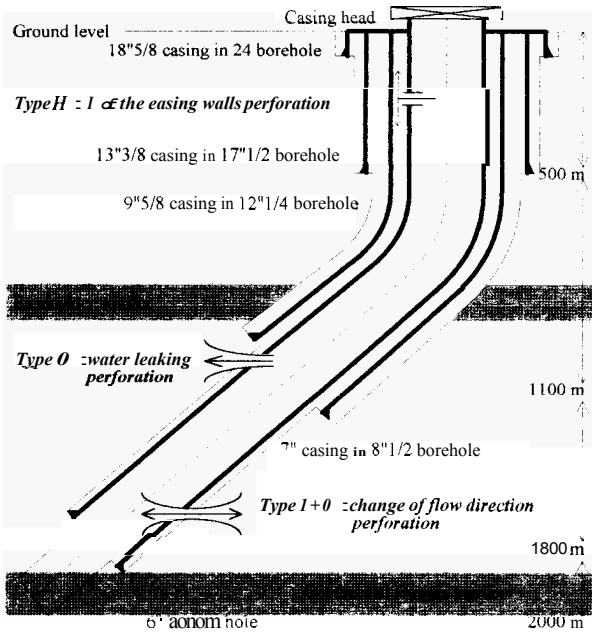

Figure 2 - Location of perforations in the injection well

2.2 Characteristics of Dogger aquifer water

The salinity of this water is comparable to sea water. It consists essentially of sodium chloride, although there are other major species such as alkali and alkaline earth metals (K^+, Mg^{2+}, Ca^{2+}), sulphates and bicarbonates. In addition, Dogger water contains dissolved gases, both neutral (mainly N_2, CH_4) and acid (H_2S, CO_2). The later, especially H_2S, tend to attack metal casings, causing corrosion and scaling which, depending on the circumstances, may lead to perforation and/or clogging of the casing. The distribution of these dissolved sulphides is not uniform. The wells in the north of the Paris Basin have a higher sulphide content than the wells in the south (Ignatiadis, 1994). The relatively high salinity of Dogger water, together with the presence of corrosive gases (CO_2, H_2S) and traces of certain detrimental species, has required the doublet method which is the use of a second well for injection (still in the Dogger but at some distance from the production area) of this geothermal water.

Even if the risk of corrosion in carbon steel (API K55) had been underestimated, a number of precautions were taken in order to limit damage in the event of casing perforation. Double casing is often used at depths (Longin *et al.*, 1994) corresponding to those of deep ground water (Neocomian, Albian) or shallow ground water. Cementation of inter-casing (inside the double casing) and casing/rock space.

There are differences in the water provided by the different aquifers in the Paris region (Rojas *et al.*, 1989). Temperature varies from 45°C to 85°C, salinity from approximately 6.5 to 35 g/l. The network of wells extends east-west from Epernay to Cergy and north-south from Creil to Fontainebleau. The pH of the fluids in the Dogger carbonate reservoir is low (6.2-6.5) as the mineralization is high, but shows no relationship with temperature it is essentially determined by the carbonated species H_2CO_3/HCO_3^-.

The most significant (and the most influential) chemical characteristic of the Dogger water is its sulphide content. This varies from a few mg/l in the south of the Paris Basin to 80 mg/l (or even more) in certain wells in the north. The sulphide content of the water from the Dogger aquifer of the Paris Basin, increases toward the north-west. The concentration of sulphides in water which initially had a low sulphide content (wells in the south and east) has increased since operations started. This increase is due to the activity of sulphate-reducing bacteria which convert sulphates into sulphides and thus encourage the formation of corrosive deposits in casings (Ignatiadis *et al.*, 1991; Ignatiadis 1994).

3. MEANS OF DETECTING PERFORATIONS

Several methods can be applied to detect perforations in well casings. Some are based on physico-chemical parameters of the fluid taken at the wellhead, some on remote monitoring of the different operational parameters of the plant, and still others on logging equipment lowered into the well.

3.1 Detection of perforations by using physico-chemical methods

These methods are based on the difference in salinity between fresh water aquifers (Albian, Brie, etc.) and the Dogger aquifer. Use of these methods requires a thorough knowledge of the characteristics of these two types of water.

Detection by measurement of physico-chemical parameters

Certain physico-chemical parameters of a given fluid, such as pH, electrode potential E_h and conductivity are highly indicative of the concentration of chemical species. Significant modification of these parameters during a routine check will indicate a change in these concentrations, i.e. the intrusion of water with a different chemical composition into the well Measuring the temperature of the fluid can reveal an incident of this nature, as the temperature of water from the Dogger is distinctly higher than that of aquifers in the overlying strata. The data appearing in this survey concerning the physico-chemical properties of the fresh water aquifers have been taken from Abou Akar, 1994 and 1995. This actual paper deals more particularly with the Albian aquifer, which is considered to be the main "strategic" reserve of drinking water in the Paris region.

The methods used to measure the physico-chemical parameters are classical *in situ* methods well adapted to geothermal waters (measurement of pH, E_h, conductivity, and temperature).

Defection of contamination of fresh water aquifer (e.g. Albian aquifer contaminated by Dogger wafer).

Table 1 shows average values of physico-chemical parameters of the Albian and Dogger aquifers, uncertainties regarding the measurements, and the minimum percentage of Dogger water that can be detected by this method.

Table 1 - Principal physico-chemical characteristics of Albian and Dogger waters and percentage detected (Dogger in Albian)
(*) No measurement available, but very different From Dogger E_h (oxidinng environment)

Average physico-chemical parameters	Albian aquifer	Relative measunng accuracy	Absolute measuring accuracy	Dogger aquifer	Percentage detected (Dogger in
pH	7 9		0 02	6 2	1 2
E_h/HNE (mV)	(*)			- 135	
conductivity at 20°C (mS)	0246	5	0012	35	004
temperature (°C)	27		0 2	70	0.5

These parameters can provide an answer as to possible perforation once the uncertainty threshold is crossed. Of these methods, conductivity is the best indicator of intrusion of water from the Dogger into the Albian aquifer. Measuring temperature to detect a possible perforation is more difficult as the history of the well prior to measuring can have great impacts, as might be the case with a well that is not in thermal equilibrium or whose tlowrate has not been stabilized.

Detection of leak from the Albian to the casing:

The percentages established for pH and temperature are the same as for the detection of a leak from the Dogger into the Albian. If we keep the same relative accuracy value in respect of conductivity, the percentage of water detected leaking from the Albian to the casing now goes to 5%, which means that measuring conductivity is the least effective way of detecting leakage in this particular direction.

Detection of perforations by analysis of water composition

The most effective infiltration indicator species are those for which: (i) there is a marked difference in content between water from geothermal wells and water from fresh water aquifers and (ii) there are sufficiently accurate measuring methods. Those elements for which there is a significant difference in content between the two types of water are shown in Table 2. For the purposes of comparison, the temperature ratio between the two types of water is between 2 and 3.

Table 2 - Chemical elements revealing the greatest difference in content between the Dogger and Albian aquifers.
(*) variations in H_2S content for the Dogger aquifer in the southern and eastern zones of Paris are not such as to facilitate detection of water intrusion Therefore this element has to be considered in wells where its level in the fluid is both constant and high (north of Paris)

Element	[ ] Dogger / [ ] Albian
Cl^-	230 to 1675
Na^+	295 to 1660
SO_4^{2-}	40 to 110
H_2S (*)	25 to 400
Ca^{2+}	6 to 75
Mg^{2+}	8 to 58
K^+	4 to 18

For the elements listed in the table above, the most accurate methods of analysis (and available at a reasonable cost) are listed in Table 3 below

Detection of leak from the Albian to the casing.

For the average geothermal water from the Dogger. it is possible to define the lower limits of the percentage of water from the Albian detectable in a mixture by chemical analysis of water taken froin the well head (Table 4)

Element	Method	Relative accuracy (Dogger water)
Cl^-	titration with $Ag(NO_3)$	< 1 %
	ICP/MS	5 %
	Ionic chromatography	10 %
SO_4^{2-}	ICP/MS	5 %
H_2S	Potentiometric titration	5 %
Ca^{2+}	Complexometric titration	< 1 %
	ICP/MS	5 %
Mg^{2+}	ICP/MS	5 %
K^+	ICP/MS	5 %

Thus it appears that the most accurate analyses, those of the Cl^- and Ca^{2+} ions, are the best tools for detecting the presence of Albian water in the Dogger As an example, in a well yielding 200 m^3/hour, it is possible to detect the intrusion of a minimum of 2 m^3/hour (33 litres/minute) of water from the Albian

Table 4 - Percentage of Albian water detectable in Dogger water by chemical analysis
(*) ONQUES sources
(**) Value obtained from recent well drilling in the Albian

Element	[ ] Dower in mg/l (average value) (A)	Relative accuracy (%) (B)	Absolute accuracy (mg/l) (A)*(B)= (C)	[ ] Albien in mg/l (average value) (*) (D)	Percentage of Albian in Dogger (v/v) equivalent to accuracy (%j (C)/((A)-(D))
Cl^-	10840	5	540	11.4	5 0
		(1)	(110)		(1 0)
Na^+	5870	5	295	6	5 0
SO_4^{2-}	870	5	44	11.6	5 1
H_2S	40	5	2	< 1(**)	5 1
Ca^{2+}	940	5	47	23.3	5 1
		(1)	(9.4)		(1 0)
Mg^{2+}	220	5	11	6.6	5 2
K^+	90	5	4.5	8.3	5 5

Note The nitrates which are present in low quantities in Dogger water may he present in shallow aquifers in much higher concentrations In fact, the nitrate content in such water is always on the increase (fertilizers, waste water) To give an example, the nitrate content of a number of fresh water aquifers compared to the Dogger is shown in Table 5

Table 5 - Nitrate average content of principal fresh water aquifers, (ONQUES sources)

Element (mg/l)	Dogger	Albian	Oligocene	Spamacian	Brie	Beauce
NO_3	0.5	0.6	21.5	39.4	40.5	60.1

Table 6 shows how the above informations may be used to trace the intrusion of fresh water into geothermal wells. In the case of Oligocene or Brie water intruding into the Dogger, measurement of the nitrates reveals in fact an intrusion value of the order of 0.1%.

Detection of Contamination of Albian Water by Dogger Water:

Where fresh water aquifers are contaminated by Dogger water, natural tracers found in the fresh water and which can indicate contamination may be taken as defined above Table 7 gives values for the most relevant elements in the case of the Albian aquifer Chlorides represent the best tracer of contamination of Albian aquifer by Dogger water Analysis of the best three tracers (Cl^-, Na^+ and Ca^{2+}) in the Albian water would enable diagnosis to be guaranteed for a percentage of Dogger water intrusion greater than 0 03% (3 litres per 10 m^3) This argument is only valid if there are no chemical reactions on contact between the two types of water in the Albian sands

Table 6 - Percentage of Oligocene and Brie water detectable in Dogger water by nitrate analysis

Concentration in Dogger (mg/l) (A)	Relative accuracy (%) (B)	Absolute accuracy (mg/l) (C)=(A)*(B)	Concentration in Oligocene (mg/l) (D)	percentage Oligocene in Dogger equivalent to accuracy (%) (C)/((A)-(D))	Concentration in Brie (mg/l) (D)	percentage Brie in Dogger equivalent to accuracy (%) (C)/((A)-(D))
0 5	5 (10)	0 025 (0 05)	21 5	0 12 (0 24)	40 5	0 06 (0 12)

Table 7 - Percentage of Dogger water detectable in Albian water by analysis of various elements.
(*) **ONQUES** sources (**) Values obtained from recent well drilling in the Albian
(***) Based on $[H_2S] = 0$ (****) Percentage tolerated for the water to remain drinkable in respect of the species considered (A Abou Akar. 1994)

Element	Concentration in Albien mg/l (*) (A')	Relative accuracy (%) (B')	Absolute accuracy (mg/l) (C') = (A')*(B')	Concentration in Dogger (mg/l) (D')	percentage of Dogger in Albian equivalent to accuracy (C')/(A')-(D')	percentage of Dogger tolerated (****)
Cl^-	11.4	5	0.57 (0.12) 0.3	10840 5870	0.005 0.001 0.005	1 74 2.45
SO_4^{2-}	11.6	5	0.6	870	0.068	27.77
H_2S	< 1 (**)	5	0.025	40	0.063	1.27(***)
Ca^{2+}	23.3	5 (1)	1.16 (0.23)	940	0.13 (0.025)	19.23
Mg^{2+}	6.6	5	0.33	220	0.15	*20.5*
K^+	8.3	*5*	0 4	90	0 51	4.57

3.2. Detection of perforations by remote monitoring

Introduction

Generally speaking, all sensors used on a low enthalpy geothermal doublet are situated either on the surface or at a shallow depth. Tests on the long-term use of pressure sensors submerged towards the bottom of the casings have not solved problems arising from temperature (80°C) or from the aggressiveness of geothermal water.

Any perforations basically occur at a depth greater than that of the sensors. Thus, detection of perforations and the resulting leaks means the interpretation of data provided by surface sensors, which consists of comparing these data with previously measured values. Therefore records do need to be kept.

The "TéléSuivi" (remote monitoring) system, which is used on about 30 geothermal installations in the Uogger, basically collects the following information:

- Pap : Pressure at the head of the producing well upstream of the booster pump (artesian wells)
- Pp : Pressure upstream of the exchanger
- Pa : Pressure downstream of the exchanger
- Pi : Pressure at injection wellhead (downstream of the reinjection pump)
- Wp : Electrical power of the production pump
- Wi : Electrical power of the injection pump
- Q : Geothermal water flowrate
- Tp : Production temperature
- Ti : Injection temperature.
- Text : Surrounding temperature.

By monitoring changes of pressure and electrical power expressed in relation to flowrate, it may be possible to obtain a probability (or risk) value in respect of perforation. Different cases may be involved, depending on casing design and use (production or injection), the nature of the surrounding rock, and the flowrate of geothermal water.

The following general hypotheses have been made concerning the working of a doublet:

Normal operation at producing well: At zero or low flowrate, pressures in a production well casing are greater than in the surrounding rocks. At medium to high flowrate, well pressures may be lower than in the surrounding rocks, the difference increasing with proximity to the surface. This phenomenon **is** due to head losses caused by friction against the sides of the casing, more especially in the case of small diameter casing and for basically negative artesian wells using submersible electric pumps.

Normal operation at injection well: At zero or low flowrate, pressures in an injection well casing are slightly higher than in the surrounding rocks. Pressure at the casing shoe is equal to that of the rock. At medium to high flowrate, well pressures are distinctly higher than in the rocks, the difference increasing with proximity to the surface. This phenomenon is due to head losses that have to be compensated by means of an injection pump.

Since pressure differences are greater, the rate of leakage resulting from perforation of the injection well is higher than for the producing well. A geothermal doublet works by regulating pressure downstream of the exchanger. The set pressure corresponds to a value slightly above that of the bubble point (approximately **8** to 10 bars).

Characteristics of principal perforations producing well

As a general rule, the risks of perforation for producing wells may be correlated with the various complementary measurements that can be taken, and more especially with chemical analyses of water taken from the well head (table 8)

Charactenstics of Principal Perforations Iniection Well

Generally speaking, the nsk of contamination following perforation is high Detection of the **risk** of perforation cannot be correlated with chemical analyses (table 9)

Table **8** - Characteristics of principal perforations in the producing well

Observations	Comments
I-type Perforation	
- Decrease in electrical power, all flowrate values - Decrease in geothermal water temperature - At zero flowrate, artesian pressure maintained (or increased) - Possible increase in maximum flowrate (at max. power) *Very low risk of contamination*	In this case, the pressure in the casing where the perforation has occurred **is always lower** than in the **rock.** This is a relatively rare case because, generally speaking, the pressure in the casing **is** greater than in the rock, particularly at a low flowrate. All things being equal, water intrusion is greater at high flowrate values. Perforations of this type are found mainly in the upper casing and pumping chambers.
0-type Perforation	
- Increase in electrical power, all flowrate values - General lowering of yield at a given power and decrease of max. yield - Decreased pressure at zero or low flowrate *Very high risk of contamination of fresh water aquifer*	In this case, the pressure in the casing where the perforation has occurred **is always greater** than in the rock. The perforation **is** located next to rock capable of absorbing geothermal water and probably at a relatively considerable depth. The perforation may be located by calculation of head losses for different flowrate values. The characteristics of the submerged pump need to be considered in order to calculate drawdown pressure.
I+O Perforation	
Leak from the casing at low or moderate lowrate - At low flowrate, increased electrical power - At zero **or** low flowrate, decreased pressure **Intrusion of water into the casing at medium or high flowrate** - At high flowrate, decreased electrical power - At high flowrate, decrease in temperature - (Possible) increase in maximum flowrate *High risk of contamination of fresh water aquifer at a low flowrate*	**This is the most likely type of perforation in a producing well.** In relation to the pressure in the rock, pressure in the casing where the perforation has occurred is **higher at a low flowrate** and **lower at a high flowrate.** This type of perforation normally occurs in the upper part of the casing, where pressure variations are greater according to the flowrate. The **rock** should be capable of absorbing and then returning the geothermal water. Calculating the location of the perforation is easier than with I and **S** type perforations as it is possible to identify a value for which the rate of leakage **is** nil. Perforations of this type notably occur in the pumping chamber.
I-0 and 0-I Perforations	
- Decrease in temperature - Variations in pressure and power characteristics according to flowrate *High risk of contamination of fresh water aquifer*	Detection is difficult as incoming and outgoing leaks partially or completely offset each other. Only chemical analysis of water from the well head can correlate the indications of temperature decrease resulting from dilution.
H-type Perforation	
Very low risk of contamination	This type of perforation cannot be detected by surface sensors.

Table 9 - Characteristics of principal perforations in the injection well

Observations	Comments
I-type Perforation	
- Increased electrical power, especially at low flowrates - Increased artesian pressure at zero flowrate *The risk of contamination is relatively low.*	In this case, pressure in the casing where the perforation has occurred is **always lower** than pressure in the rock. This type of perforation is relatively rare, even at a low flowrate, as pressure in the casing is greater than in the rock. Water intrusion is usually greater with low flowrates. At a high flowrate, measured values remain close to normal.
O-type Perforation	
- General decrease in electrical power - General decrease in injection pressure *Very high risk of contamination of fresh water aquifer*	**This is a more likely type of perforation with the injection well.** Pressure in the casing where the perforation has occurred is **always greater** than in the rock. It is difficult to calculate the location of perforations of this type.
I+O Perforations	
- Increased injection power and pressure at low flowrate - Decreased injection power and pressure at high flowrate *Relatively high risk of contamination of fresh water aquifer at high flowrate.*	In relation to the pressure in the rock, pressure in the casing where the perforation has occurred is **lower at a low flowrate** and **higher at a high flowrate**. This type of perforation is normally located in the upper casing, where pressure variations as a function of flowrate are greatest. Calculating the location of the perforation is easier than for simple I or O types as it is possible to identify a value for which the leakage rate is zero.
I-O and O-I Perforations	
- Very little change in pressure and power characteristics in relation to flowrate *The risk of contamination of fresh water aquifer does exist.*	Detection is virtually impossible as incoming and outgoing leaks partially or completely offset each other.
Type-H Perforations	
Very low risk of contamination	This type of perforation cannot be detected by surface sensors and requires the use of equipment lowered into the well. The cement used to fill the space between casings may be adequate for long-term prevention of leaks.

4. DISCUSSION

Measurements of the physico-chemical parameters and/or chemical analysis of the composition of a geothermal water at the prodution wellhead have been shown to represent a very effective and highly accurate method for detection of the perforations defined as I, I-O, O-I and 1+0 (in I mode) in the introduction. The use of physico-chemical methods for detecting I, I-O, O-E and 1+0perforations in the injection well **is** somewhat dubious as it means shutting down the installation in order to put the injection well into production, which is prohibitively expensive and only done when the plant itself is shut down. However, it is possible to modify the pressure levels in the well and consequently detremine flowrates and directions of any leaks. These physico-chemical methods could be also used for revealing H-type perforations if the geothermal fluid is capable of flowing up to the surface into the annulus between casings.

0-type perforations concern the contamination of a fresh water aquifer by water from the Dogger, and therefore cannot be detected by chemical analysis of the geothermal fluid at the head of the producing or injection well. It can, however, be detected by chemical analysis of the water pumped into the fresh water aquifer, contamination being revealed by the presence of geothermal water. This method is not without its disadvantages:

- It cannot identify the origin of the water as there may be a number of other wells in the zone at risk. However, known data on the geological strata and water migration patterns can help to reduce the number of wells likely to be responsible.

- It is more probable that too long a time elapses before detection threholds are reached at the pumping station, which will cause major contamination of the aquifer concerned.

This means that 0-type perforations have to be detected by remote monitoring (§ 3.2).

It should also be noted that the service conditions ofthe doublet (the yield) may, when they vary, change the direction of the leak as the result of pressure changes within the casings. For example, a leakage of geothermal water at pump-room level may turn into intrusion of water from the outside when the well yield increases (and the hydrodynamic level goes down). This would be an 1+Osituation.

5. CONCLUSIONS

Numerous methods can be used to detect a casing perforation in a given well :

Those which are based on measurement of physico-chemical parameters of fluid at the well head are useful in detecting the following types of perforations in the production well: I, I+O (I mode), I-O and O-I.

Measurement of physico-chemical parameters at the injection well head necessarily requires the well production. This induces some problems (shutting down the installation, modification of flowrate and direction of the leak). Under special conditions these methods can be applied to detect the H-type perforation both in production and injection wells They are also capable detecting the 0-type perforation by chemical analysis of water at the aquifer pumping station but with some major disadvantages such **as** long delay and prolonged pollution

Other methods based on remote monitoring of operating parameters allow a rapid detection of a possible perforation

- for the **I, O,** and I+O type perforation this method is effective for both production and injection wells,
- for the I-O and O-I type perforation this method is less effective,
- for the H-type perforation this method cannot be used

In all cases indication given by remote monitoring must be confirmed **by** chemical analysis, and if necessary by using downhole logging equipment

Acknowledgments: This is the BRGM contribution N°95002 rhis work was carried out in the framework of the Commission of European Communities contracts N° JOUG-0005-C and N°JOU2-CT92-0108, and received financial support from a BRGM research project (S08)

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