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DEVELOPMENT OF EXPERT SYSTEM FOR LOST CIRCULATION PROBLEMS

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ABSTRACT

Lost circulation (LC) is the phenomenon where circulating drilling fluid is lost to fracture or porous in the rock formation rather than returning to the surface. For drilling geothermal well, LC can be serious problem that contributes greatly to the cost of the average geothermal well and completion of the well.

We studied "The research and development of lost circulation techniques in geothermal wells" to permit systematical lost circulation treatment undertaking committed by the New Energy and Industrial Technology Development Organization (NEDO) from 1986 to 1990, whose program consists of detection of LC analysis techniques, plugging materials, and treatment techniques.

In this project, the expert system for lost circulation problems, so-called LC expert, was developed to support determination of LC treatment method for drilling engineers. The LC expert suggests drilling engineers to design the optimum LC treatment. We believe these suggestions would reduce uncertainty and mistake in decision process of field personnel.

Developed LC expert designs the optimal solutions for LC treatment according to the information obtained from the LC detection tool and its data processing, knowledge base including experiences of drilling experts, properties of each plugging materials, knowledge obtained from simulation test, and knowledge from field test.

It was evaluated by drilling experts and actual field tests that the LC expert inferred the LC treatment method quite adequately.

1. BACKGROUND OF DEVELOPMENT

Drilling cost is approximately 50% in geothermal energy development, so it is very important for geothermal developers to reduce the drilling cost.

Lost circulation is one of the most difficult obstacle for treatment which we encounter during drilling or completion of wells. We have a large size of LC quite frequently in geothermal drilling rather than oil/gas well. And further LC also would be the cause of formation collapse and/or stuck of drill strings, and cause of failure of casing cementing which is very important when geothermal fluid is produced.

To solve the lost circulation problem, we develop the LC expert system which is systematical and effective system to suggest optimum treatment using AI (artificial intelligence) technology.

LC expert system can exclude the method of trial and error owing to development of LC zone detection and analysis techniques as well as optimum plugging materials and treatment processes.

2. POSITION OF LC EXPERT SYSTEM IN LC R&D PROJECT

Whole subjects of "The research and development of lost circulation techniques in geothermal wells" are shown in Fig. 1. In this figure, LC expert is not main subject in the project. However, we consider this is very important for the project, because this system manages all information and data obtained at the field.

3. OUTLINE OF THE LC EXPERT

3.1 Object

The object of LC expert system development is to select optimum LC treatment method corresponding to the lost circulation characterization. To develop the LC expert system, we represent following items on the computer to support determination of LC treatment method.

(a) Effective experienced rules of drilling engineers
(b) LC zone detecting system (developed item)
(c) Analysis programs of LC characterization (developed item)
(d) Plugging materials and treatment method (developed item)
(e) Simulation test of plugging process (developed item)
(f) Well test (developed item)

Then the expert system includes all developed items in the LC R&D project. And the system can support drilling engineer according to the situation of each LC condition at the field.

The general advantages of expert system are as follows.

(a) It is possible to judge from a lot of data, rather than limited experience of engineers as usual now.
(b) It is possible to judge correctly, even in case judgment is required in hurry, because the system judges from knowledge base.
(c) We can use more clever LC expert if the knowledge base is refined.

3.2 Structure and Function of the LC Expert

LC expert is the computer system which infers the result from rules based on the knowledge base. Based upon the characterization of LC zone, knowledge from experiences

of drilling engineers, properties of plugging materials, and results of simulation test, LC expert infers the treatment method according to information. If the treatment is succeed, the result is recorded in the hard disk of LC expert system. When, however, the treatment is failed, the system diagnoses the reason of failure and determines retrial method.

LC expert is composed of following three essential components.

(1) Tool for knowledge engineering

The first component is tool for knowledge engineering which is composed of knowledgebase, inference engine, knowledge control system, and user interface. Knowledge base includes rules from experiences of drilling experts, data from detection test, and simulation test of the plugging materials. The rule composes rules for presumption of LC characterization which infers LC geometry (severity, zone, depth, and type), rules for determination of treatment method which infers the definite treatment method/procedure (plugging material and injection method) according to information of treatment object etc., evaluation (treatment result), rules for diagnosis of failure which diagnoses according to the treatment result, rules for determination of retrial treatment method which depends on the result of diagnosis of failure, and rules for system control including communication with user-interface.

The expert system infers LC treatment method using the input data in each step and conducts the result. The LC expert can be used for "general inference" which infers all steps of rules and "individual inference" which can infer specific step is available, then users can select the system depending on their purpose. Flowchart of "general inference" of LC expert system is shown in Fig. 2.

The LC expert system can conduct some recommendations rather than one if the results have some possibility or effectiveness. So that operator has the final decision, because the purpose of this system is to support of determination of drilling engineer and it is difficult to decide the only one LC treatment from present LC technology.

(2) User-interface program

The second component is user-interface program which is composed of following nine screens.

(a) Data input screen
(b) Output of inference result screen
(c) Help screen
(d) LC detection/pressure analysis/temperature analysis screen
(e) List of LC records screen
(f) Material stock screen
(g) Well graphics screen
(h) System flowchart screen
(i) Fortran program (calculation) screen

Screen of data input has seven screens which are presumption of LC characterization, determination of plugging material, determination of injection method, determination of treatment method, evaluation, determination of retrial treatment, and record screens. All these screens have function of output of inference result, help, list of LC record, stock of materials, well graphics, system flowchart and calculation programs, and users can refer to one of these function in any time. User-interface displays Japanese characters for Japanese.

(3) Application programs

The third component is application programs which are composed of calculation programs, mud properties, properties of materials, reference from LC records, etc. We can select these applications in the input screen at any time.

3.3 Computer System for Development

(1) Hardware

Model: HP9000/375
CPU: Motorola 68030 (33MHz)
Memory: 32MB
Hard disk: 132MB (OS)
571MB (programs and knowledge base)

(2) Software

OS: HP-UNIX Version 7.0
Language: C
Fortran
Tools for knowledge engineering
Window system: X WINDOW X-II

4. KNOWLEDGE BASE

Knowledge base is one of the most important element in expert system and it dominates quality of the system. Improvement method of knowledge base for LC expert is shown in Fig. 3.

For knowledge acquisition of experiences of drilling experts, we tried many approaches such as discussion with drillers on LC treatment to drilling experts and field test. And we included the rules obtained from LC detection system and simulation test results of plugging materials.

It is difficult, in general, to evaluate system only from number of rules, however as one of indexes, progress of rule numbers is shown in Fig. 4. Total rule number of knowledge base is 338 rules.

5. EXAMPLE OF INFERENCE

Item of input and output in each inference step is shown in Table 1.

We show some input/output examples of LC expert in Figs. 5 to 13. The mouse is basically used for system operation to allow easier and quicker.

6. EVALUATION OF LC EXPERT

For the evaluation of the developed LC expert, we conduct user's test twice by drilling engineers who are related to geothermal energy development, in 1990. Through improvement of the problems which were pointed out about knowledge-base and user-interface, we developed better operability and high performance system.

We tested the developed expert system for the lost circulation which occurred 16 times in the LC-1 well

drilled as a test well for the LC R&D project. In these tests, drillers used the same materials six times as the expert system inferred in six times lost circulation. And they succeeded to plug the lost circulation three times.

It was concluded that the system generally inferred the treatment method quite adequately and no error was caused during the operation.

7. CONCLUSIONS

We drew following conclusions and future research from the work in this report.

(a) The LC expert could suggest support optimum LC treatment method according to the LC characterization obtained from the LC detection tool and analysis, knowledge base including experiences of drilling experts, and properties of plugging materials obtained from simulation tests.
(b) The LC expert was evaluated by drilling experts and field tests that the LC expert inferred the treatment method quite adequately and good performance of operation.
(c) Using this system, it is possible to get procedure of optimum LC treatment quickly.

If we have an opportunity in future, we would like to polish up and expand rules and knowledge base, and make system working with portable computer. Then this expert system will become more practical tool, we believe.

ACKNOWLEDGMENTS

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REFERENCES

Messenger, J.U. (1981), "Lost Circulation," PennWell Publishing Company, Oklahoma.

Hayes-Roth, F., Waterman, D.A., and Lenat, D.B. (1983), "Building Expert Systems," Addison Weley Publishing, Massachusetts.

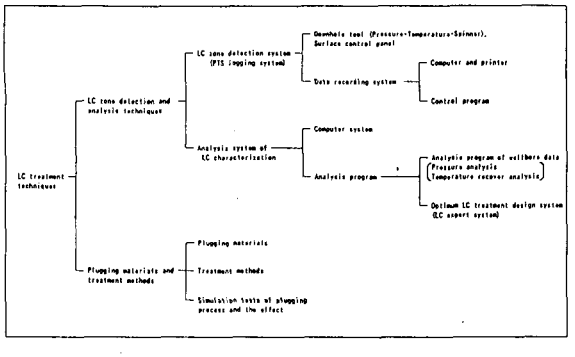


Figure 1 Research subjects of LC R&D

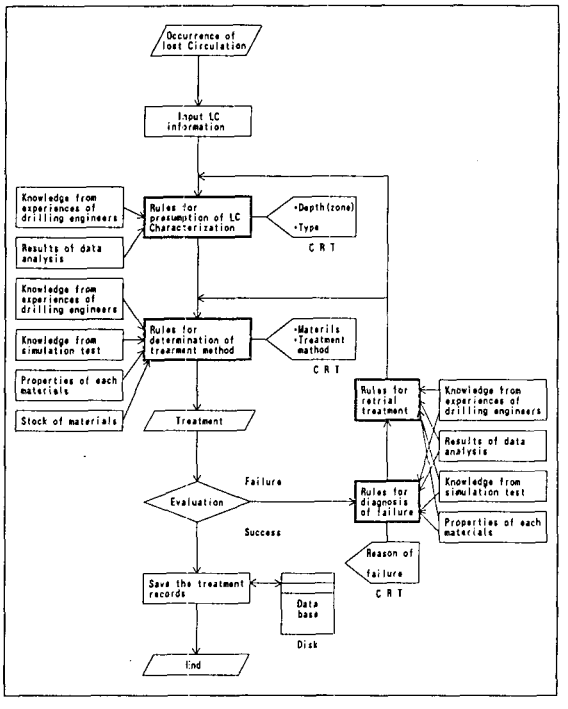


Figure 2 Flowchart of LC expert

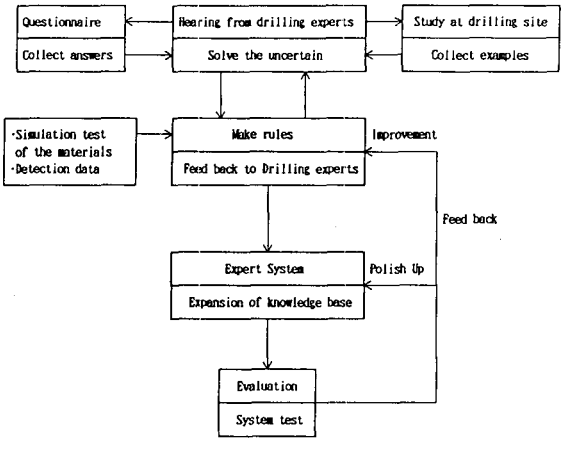


Figure 3 Improvement of knowledge base for LC expert

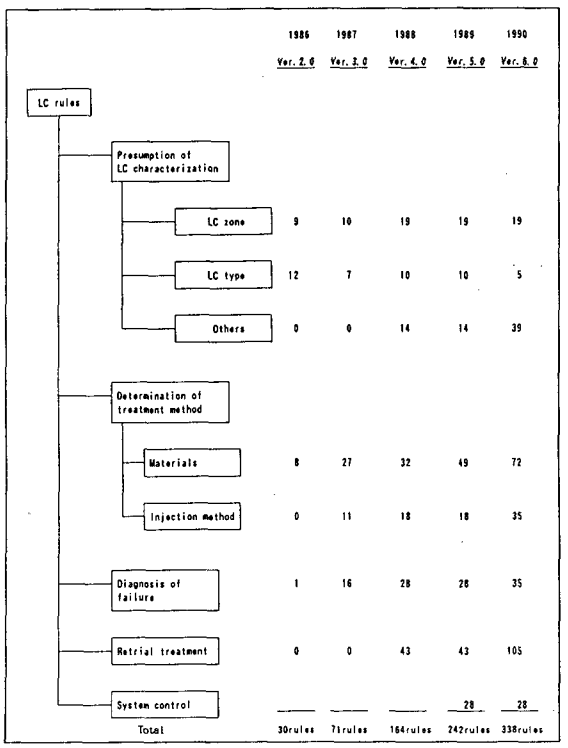
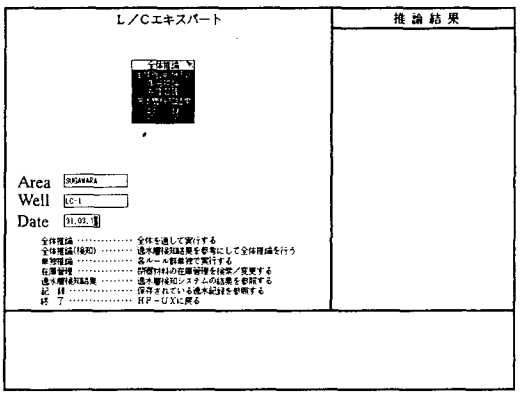


Figure 4 Rule structure and progress of rule numbers

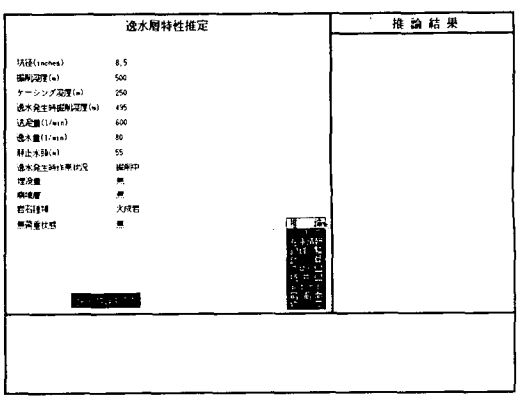
Table 1 Input/output in each inference step

Step	LC characterization	Materials	Injection method	Result/Retrial	Record
Input	Well name well diameter Well depth Casing shoe depth Depth when LC occurred Loss rate Pump rate Fluid level Operation when LC occurred Bottom fill Collapse formation Rock type Bit weight	Purpose/ Completion Mud density Estimated temperature LC zone LC depth LC severity LC type	Material Cement density Cement volume Density of LCM slurry LCM slurry volume Bit nozzle size LC severity LC zone LC depth Mud density Estimated temp. Pump rate Loss rate	Result Pump rate Loss rate Fluid level Lost cement volume Lost LCM volume TOC Relapse depth	No Well Area Date Depth Loss/Pump rate material method result
Output	·LC depth ·LC severity ·LC type	·Plugging materials	·Injection method	·Reason of failure ·Retrial method	



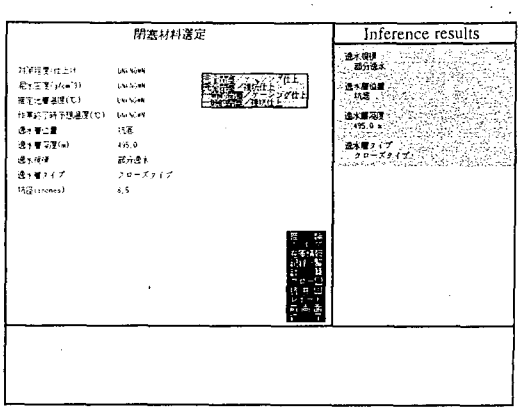
Select from 1) General inference, 2) General inference with detection system, 3) Individual inference, 4) Stock information of materials, 5) LC detection (PTS) analysis, and 6) LC data base (records).

Figure 5 Initial menu



Input 1) Well diameter, 2) Well depth, 3) Casing depth, 4) Drilling depth when LC occurred, 5) Pump rate, 6) Loss rate, 7) Fluid level, 8) Operation when LC occurred, 9) Bottom fill, 10) Collapse formation, 11) Rock type, and 12) No load condition.

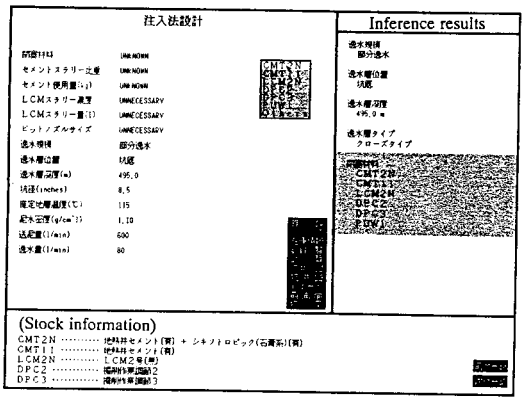
Figure 6 Input LC information for presumption of LC properties



Input 1) Purpose/completion, 2) Mud density, 3) Estimated formation temperature, and 4) Estimated temperature after treatment operation.

Inference results: 1) Severity of lost circulation, 2) LC zone, 3) LC depth, and 4) LC type.

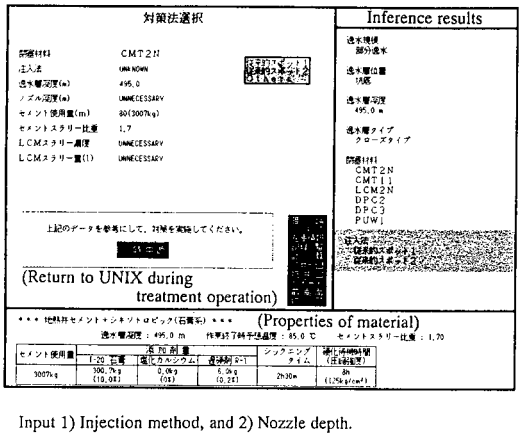
Figure 7 Determination of treatment material



Input 1) Plugging material, 2) Density of cement slurry, 3) Cement volume, 4) Density of LCM slurry, 5) LCM slurry volume, and 6) Bit nozzle size.

Inference results: Recommended materials.

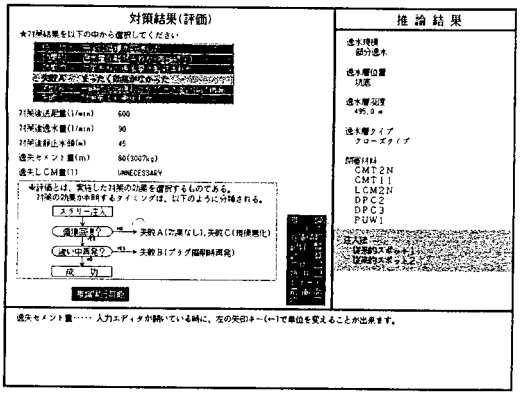
Figure 8 Determination of injection method



Input 1) Injection method, and 2) Nozzle depth.

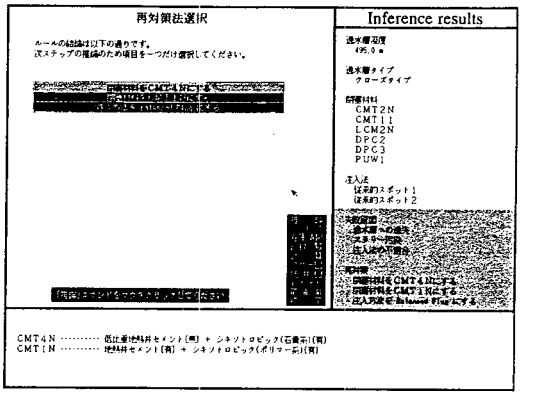
Inference results: Recommended injection method.

Figure 9 Determination of treatment method



Select from 1) Circulation recover completely, 2) Effective, reduce loss rate (finish), 3) Effective, reduce loss rate (continuance), 4) No effect at all, 5) Relapse when drilling out LC zone, and 6) Become worse.

Figure 10 Input of treatment result



Input Retrial treatment method.

Inference results: 1) Reason of failure, and 2) Recommended retrial treatment method.

Figure 11 Determination of retrial treatment

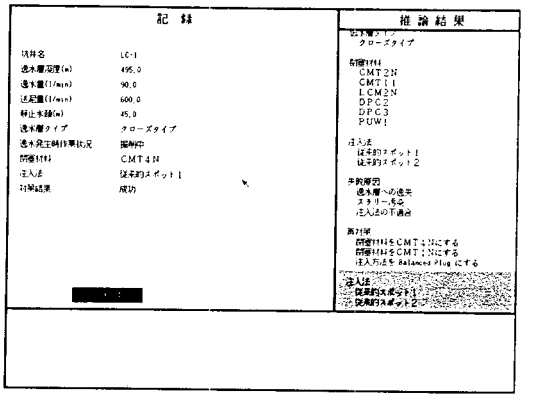


Figure 12 Recording

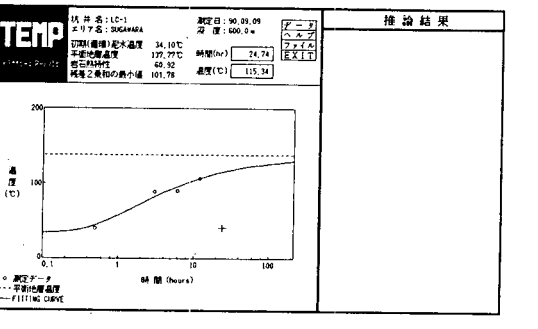


Figure 13 Example of temperature recovery analysis