SCHECK, D.E., CHATTERJEE, P.K. and WEI SUN, M.S. Surface mine blast design and consultant system. APCOM 87. Proceedings of the Twentieth International Symposium on the Application of Computers and Mathematics in the Mineral Industries. Volume 1: *Mining*. Johannesburg, SAIMM, 1987. pp. 181 – 188.

Surface Mine Blast Design and Consultant System

D.E. SCHECK, P.K. CHATTERJEE and M.S. WEI SUN

Department of Industrial Systems and Design Engineering, Ohio University, Athens, Ohio, USA

A computer-aided blast design consultant system has been developed. The software consists of two modules: one uses theoretical and empirical formulae and procedures to design a blast based on user supplied geological and mechanical data, while the other is an expert system that analyzes blast vibration problems and recommends remedial action using knowledge based rules. The system is currently undergoing field evaluation.

Introduction

The methods of blasting overburden in surface coal mines vary with the characteristics of the formation, its depth, and the type of mechanical equipment available for its subsequent removal. Since the size and depth of drill holes, drilling pattern, grade and type of explosives, and the loading and firing techniques will have a significant impact on the overall productivity of the mining operation as well as the adverse effects on the surrounding environment, the need exists for a system to design blasts in accordance with good practice and to identify solutions to blasting problems.

Blast design procedures have been reduced to formulae and an algorithmic process[1,2] which can be programmed for a computer using conventional procedural language. Since the procedures are based on idealized conditions, there will always be some discrepancy between design expectations and the observed results. When this discrepancy is significant, blast problems may become severe, for example, vibration levels and airblast levels can exceed acceptable levels. If this situation occurs, adjustments to the blast design must be made. Relating blast effects to specific design parameters may be difficult since some results such as excessive backbreak or poor fragmentation can only be described subjectively.

Interpreting these observed results, identifying the cause and suggesting remedial actions often requires the advice of an experienced, professional blasting engineer.[3] Since such persons may not be readily available or too expensive to use on a continual basis, the possibility of capturing the expertise and reducing it to computer code is very appealing. The availability of recently developed artificial intelligence (AI) software tools has made such a task a feasible endeavor.[4,5]

Numerous practical applications of AI technology have emerged recently.[6] Of the three basic AI categories (expert systems, natural-language systems, and perception systems for vision, speech, and touch), expert systems are the leading practice. Expert systems are programs that use humanlike reasoning processes to solve problems in a particular application area. These programmed reasoning processes are constructed from experiential human knowledge or expertise which is encoded in a program structure called a knowledge base. This encoded knowledge and reasoning mechanism are reduced to a set of rules that could be programmed in a conventional high level language, but special purpose languages, such as LISP or Prolog, make program development a much easier task.

This paper outlines the use of a higher level language (Golden LISP) to develop an expert system for surface mine blast design.

Objective

The objective of this investigation was to develop an interactive blast design program that guides the user through the various blast design steps and provides an 'expert' system to evaluate the results of post-blast vibration and airblast observations. The three major subgoals of this project were:

1. To develop an interactive computer program to help the user to design a blast using empirical formulae.
2. To obtain expert knowledge to build a knowledge base for the diagnosis of blast vibration problems.
3. To construct a consultative expert system which is capable of using expert knowledge to discover deficiences in a blast design and offer expert advice based on post-blast observations.

The need for the third subgoal relates to the subjective nature of the blast evaluation process. Because the number of factors which can cause poor blasting results is very large and each factor can have many levels, a simple procedure to identify the cause of a blast problem is not possible. In addition, symptoms of a poor blast are usually described qualitatively because of the difficulty of obtaining quantitative measures. Therefore, it is impractical to develop a totally mathematically based blast evaluation procedure.

Since the diagnosis of a blasting problem relies heavily on personal knowledge and experience of an expert to reach a conclusion, expert opinion is probably the only practical approach to solve such a multivariable problem. If this expertise is imbedded in an expert system program, the system could prompt the user to describe the blast results and the computer could reach conclusions based on the stored information. This process is a consultative expert system, and the rules form a knowledge base.

System design

The system consists of two distinct modules as shown in Figure 1. One module is an interactive program that assists the user in designing a blast. Theoretical and empirical formulae are the basis of the design, and no knowledge based expert system is required. The other module is a consultant system

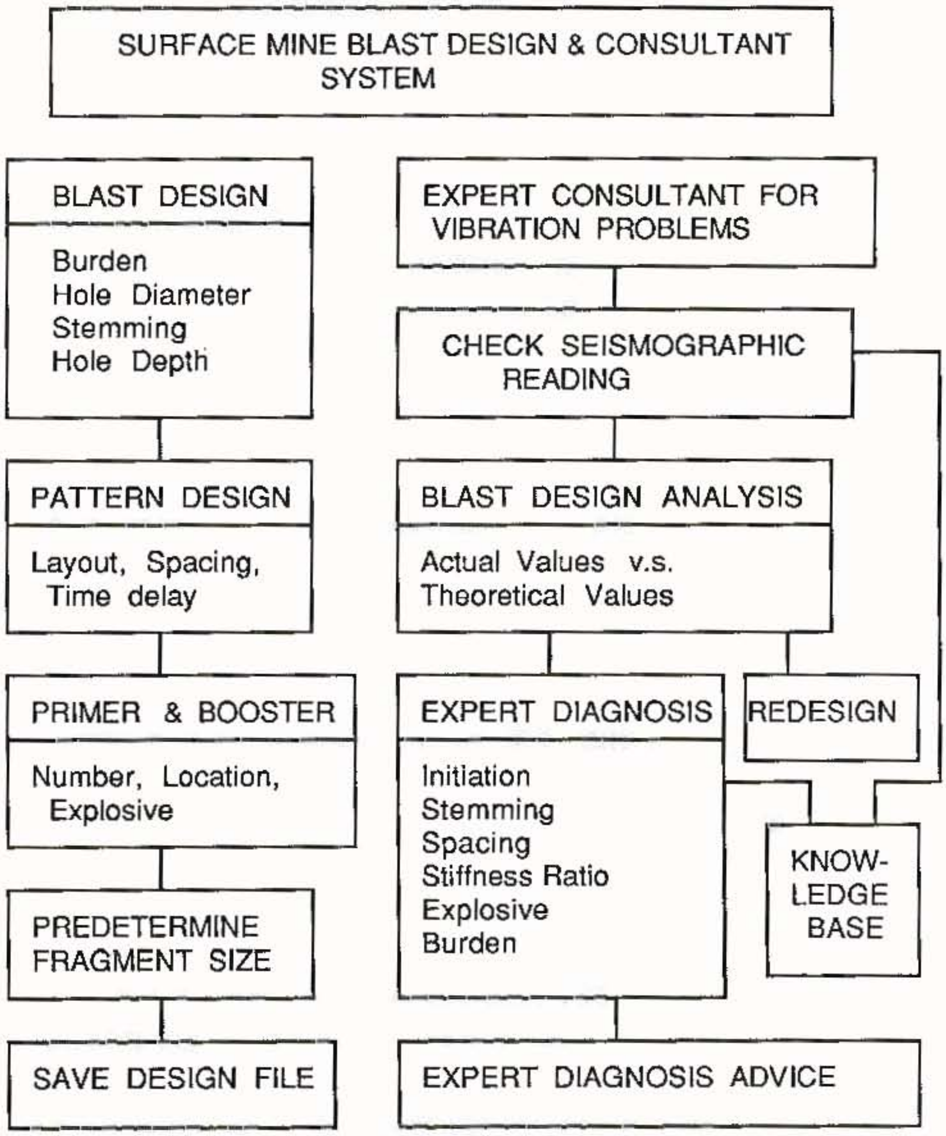

FIGURE 1. Surface mine blast design and consultant system

to diagnose apparent blasting problems based on post-blast observations. The two modules can be used independently or sequentially. If the blast was designed outside the program, the consultant module will ask the user to enter the design parameters and related data. The system first checks to see whether the design follows good practice before attempting to resolve any apparent problems.

The blast design module uses generally accepted rules that have been developed from theoretical and empirical studies which are well documented in the literature. A typical menu from these modules is given in Figure 2. After soliciting the required information from the user, the system generates a recommended design such as the parameters shown in Figure 3. Interactive graphics help the user interpret the design.

The consultative module is a true rule-based expert system and is different from the design module. The post-blast analysis system is limited to vibration effects. The

PROGRAM MENU

1. BLAST DESIGN
2. PATTERN DESIGN
3. PRIMER AND BOOSTER SELECTION
4. PREDETERMINE FRAGMENT SIZE
5. SAVE THE DESIGN RESULTS
6. BLASTING PROBLEM CONSULTATION
7. ABORT THE SESSION

(PLEASE INPUT THE NUMBER OF DESIRED FUNCTION)

YOUR INPUT

FIGURE 2. A typical design menu

BLAST DESIGN PARAMETERS

ROCK TYPE: SHALE

EXPLOSIVE TO BE USED: POURED ANFO
BENCH HEIGHT: 120 (FT)

1. STIFFNESS RATIO = 4
2. BURDEN = 32 (FT)
3. CHARGE DIAMETER = 15 (INCHES)
4. STEMMING LENGTH = 22 (FT)
   NOTE: SMALLER STEMMING LENGTH COULD BE USED.
   AVERAGE SIZE OF STEMMING MATERIAL = 0.75 (INCHES)
5. BLASTHOLE DEPTH = 120 (FT)
6. SUBDRILL = 0 (FT)

IF NOT SATISFIED, ENTER <R> TO REDESIGN OTHERWISE,
ENTER <M> TO RETURN TO THE MAIN MENU.

FIGURE 3. Recommended design parameters

THIS IS AN INTERACTIVE PROGRAM. YOU WILL BE ASKED TO
ANSWER QUESTIONS TO RESOLVE YOUR BLAST PROBLEM.

WHAT IS THE EVIDENCE OF VIBRATION?
1. SEISMOGRAPH READING.
2. HUMAN COMPLAINTS.
>>2

IS A SEISMOGRAPH READING AVAILABLE?
1. READING IS AVAILABLE.
2. READING IS NOT AVAILABLE.
>>1

IS THE READING OK?
1. READING IS OK.
2. READING IS NOT OK.
>>2

FIGURE 4. Vibration problem questionaire

system first asks a set of questions as shown in Figure 4, to identify that a vibration problem actually exists. If the data are not conclusive, the system recommends that the user observe another blast to ensure that valid seismograph readings are obtained.

If the data indicate that a problem does indeed exist, the system will ask for the design parameters and then generate a recommended design using the blast design module. The actual versus designed values are listed and significant discrepancies highlighted. The user then has the option to modify the design to meet the suggested values and try another blast or proceed to the diagnostic part of the module.

A portion of the vibration problem verification logic flow chart is given in Figure 5, several steps in the diagnosis process are shown in Figure 6. Typical suggestions appear on the screen such as given in Figure 7. A hard copy of the recommendations is also provided.

Discussion

The blast design and consultant system is programmed in Golden LISP for the IBM PC/AT and compatibles. Six hundred and forty Kbytes are required to run the program and a color graphics monitor is used to communicate with the user and to display the results. The current version of the consultant module incorporates only vibration related effects but the system is designed for expansion. Work is continuing on a segment to analyze fragmentation problems.[7]

At the present time the system has not been field proven. A blasting

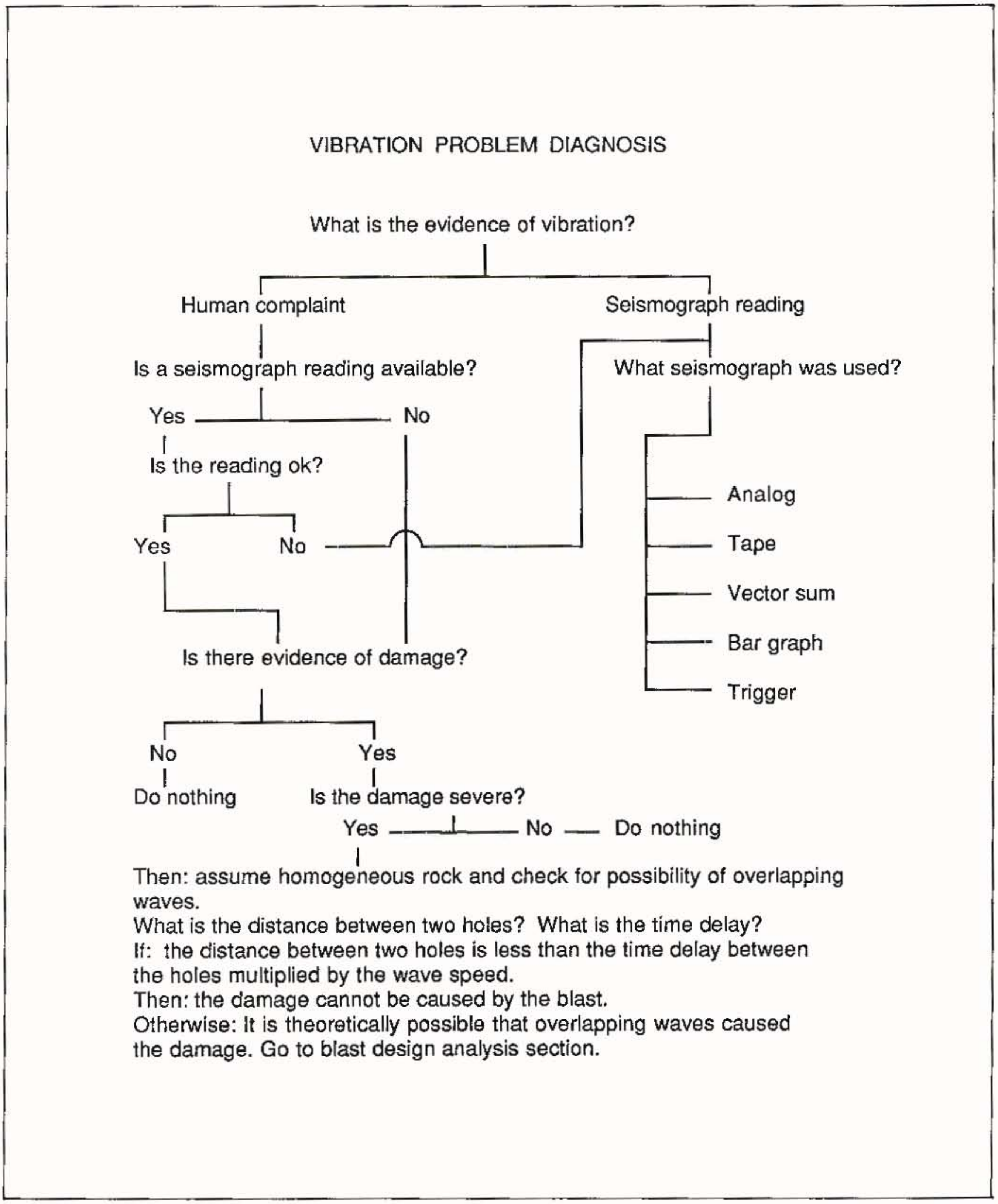

FIGURE 5. Vibration logic chart

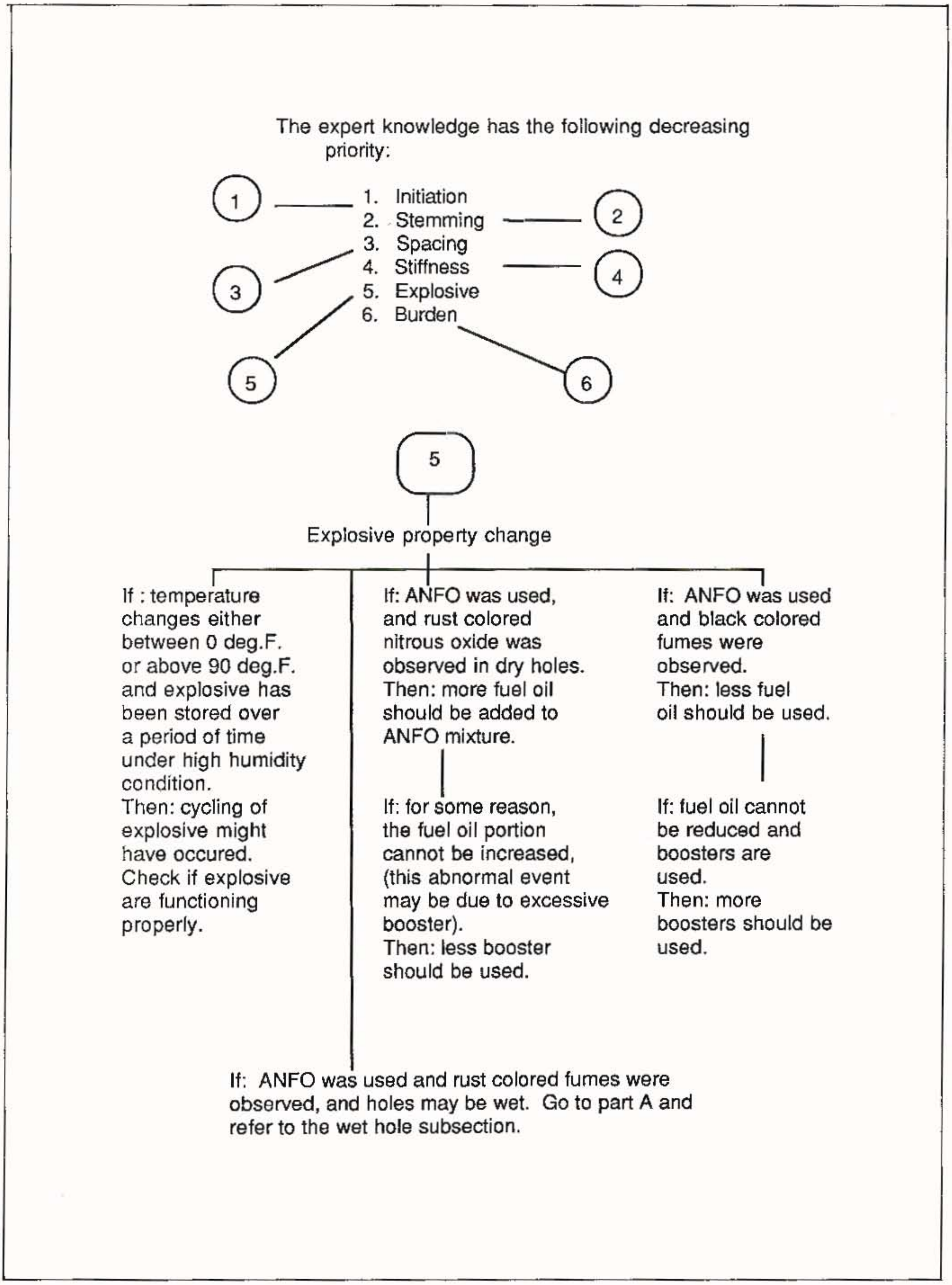

FIGURE 6. Steps in a diagnostic process

expert provided information for the knowledge base and has subjectively evaluated the system's recommendations. The system has been provided to a blasting service for their use and evaluation.

References

1. KONYA, C.J. and WALTER, SR., E.J. Rock blasting. U.S. Department of Transportation,1985.

2. ATCHISON, T.C. Fragmentation principles. Surface Mining. American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 1968.

3. DUVALL, W.I. AND DEVINE, J.F. Avoiding damage by air blasts and ground vibrations from blasting. Surface Mining. American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 1968.

4. BUCHANAN, B.G. and SHORTLIFFE, E.H. Rule-based Expert Systems. Addison-Wesley Publishing Company, Inc., 1984.

5. RAUCH-HINDIN, W.B. Artificial Intelligence in Business, Science, and Industry. New York. Prentice-Hall, Inc., 1985.

6. WINSTON, P.H. and BROWN, R.H. Artificial Intelligence: An MIT Perspective, vol. 1. Cambridge, Mass, The MIT PRess, 1979.

7. GOZON, J.S. BRITTON, R.R. and FODO, J.D. Predetermining average fragment size: a case study. Society of Mining Engineers, Denver, Coloardo, Preprint, 1986.

RULE ID1 ASSERTS:
(INPUT <WHY> TO CHECK THE INFERENCE, <ENTER> TO CONTINUE)

POWDER LOAD PER DELAY SHOULD BE REDUCED.

WHY
BECAUSE:

PARTICLE VELOCITY READ IS LESS THAN TWICE THE PREDICTED VALUE.

RULE ID2 ASSERTS:
(INPUT <WHY> TO CHECK THE INFERENCE, <ENTER> TO CONTINUE)

REDUCE THE POWDER LOAD PER DELAY TO THE RECOMMENDED AMOUNT WHICH IS EQUAL TO THE SQUARE OF THE SENSOR DISTANCE DIVIDED BY 50.

RULE ID6 ASSERTS:
(INPUT <WHY> TO CHECK THE INFERENCE, <ENTER> TO CONTINUE)

TIME DELAY SHOULD BE USED IF APPLICABLE.

RULE ID8 ASSERTS:
(INPUT <WHY> TO CHECK THE INFERENCE, <ENTER> TO CONTINUE)

SPECIFIC GRAVITY OF THE PRIMER SHOULD BE GREATER THEN 1.2 AND DETONATION VELOCITY GREATER THAN 15000 FEET PER SEC. PRIMER DIAMETER SHOULD ALSO BE GREATER THAN THE CRITICAL DIAMETER OF THE MAIN CHARGE.

FIGURE 7. Consultant expert advice