11 Drilling Data Acquisition

What CCSD-1 Well encountered were not only the deep hole to be drilled but also the complex formations to be met, and then a wide variety of drilling technologies were adopted during the difficult constructions. In order to improve drilling efficiency and reduce drilling accident, drilling process monitoring must be strengthened, so as to improve the levels of on-site monitoring, decision-making at drill site and drilling data processing. So a complete set of drilling data acquisition and processing system was indispensable for deep well drilling, which could assist to identify the bottom-hole conditions, improve the level of drilling decision-making, and reduce accidents and construction costs. At the same time, the drilling data acquisition system was also an important data source for drilling management.

As the drilling technologies for continental scientific drilling are different from others and the bottom hole conditions reflected by the drilling parameters are not the same, the drilling monitoring strategy and contents must be studied based upon the special construction characteristics of the continental scientific drilling. Drilling data acquisition system includes two parts, the surface data acquisition system and the down-hole data acquisition system. And the surface data collection consists of two systems, comprehensive geological logging system of the comprehensive geological logging company and the drilling data gauges equipped on the drill rig (with computer data acquisition system). In the actual construction, the comprehensive geological logging system had a powerful function and high specialization degree, collecting data comprehensively, therefore the comprehensive logging system was used as the primary data acquisition system, while the drilling data gauges for real-time monitoring in the drilling process.

Translated Li Haipeng.

11.1 General Situation

Since CCSD-1 Well is the first continental scientific exploration well in China, comprehensive logging instruments specifically for continental scientific drilling were unavailable in market. Although the comprehensive logging instrument for oil drilling could basically satisfy the need of continental scientific drilling, a certain improvements must be made in the software and hardware for data acquisition, and more improvements in the data processing software and application software to meet the needs of drilling data acquisition and processing at surface for continental scientific drilling.

Petroleum exploration comprehensive logging instrument is a large scale mechanical and electrical integrated apparatus for oil and gas exploration services, which can collect real-time drilling parameters, drilling fluid gas logging (CO_2, CH_4, H_2S, etc.) parameters, continuously monitor oil, gas and down-hole drilling conditions, and make evaluations. There are several manufacturers producing different brands of comprehensive logging instruments for petroleum exploration in the country. SDL9000 comprehensive logging instrument jointly developed by Petrochina Shanghai Petroleum Instrument Co. Ltd, China Technical Service Beijing Geological Logging Technology Company and US Halliburton Company, is a new generation of comprehensive logging instrument with the international advanced level. DLS-CPSIC comprehensive logging instrument jointly developed by the US International Logging Company and Petrochina Shanghai Petroleum Instrument Co. Ltd, with the international advanced level of the 21st century, can be used not only on land drilling platform, but also on offshore fixed and floating drilling platforms. Drillbyte comprehensive logging instrument produced by Shanghai Shenkai Science & Engineering Co. Ltd authorized by Beck Hughes Inteq Company is a large scale comprehensive logging instrument with the advanced Drillbyte Ver 2.3 system software and other related systems introduced from Hughes Inteq Company.

D. Wang et al., *The China Continental Scientific Drilling Project*,
Springer Geology, DOI 10.1007/978-3-662-46557-8_11

Fig. 11.1 The internal units of SK-2000FC/C comprehensive logging instrument developed by Shanghai Shenkai company

SK-2000FC/C comprehensive logging instrument (Fig. 11.1) developed by Shanghai Shenkai Science & Engineering Co. Ltd under the bases of absorbing foreign advanced technology and experience accumulated over years and depending on the scientific and technological superiority of the company and strong industrial base in Shanghai, is a new generation of important instrument for petroleum exploration, occupying a leading role in domestic market in overall design and manufacturing technology and reaching the international advanced level. Various brands of comprehensive logging instruments are similar in technical indexes and in functions, with the main differences in sensor performance, computer hardware structure and the software functions, etc. In recent years, China has introduced a large number of comprehensive logging instruments produced by foreign manufacturers, which not only have the complete comprehensive logging functions, but also have the remote transmission function of real-time data and data files. However, some of them lack the corresponding hardware equipment and software systems, and few though have a data file transmission system but can not used for real-time data transmission. Most of domestic comprehensive logging instruments do not have real-time data transmission function (Figs. 11.2 and 11.3).

Because of the high cost, the down-hole drilling parameter detection instruments are generally used only in the deep or complex well drilling constructions with greater investment. The down-hole drilling parameters detection measurements are divided into the measurement-while-drilling and non-measurement-while-drilling, and the measurement-while-drilling is divided into the wired and the wireless measurement. The wireless measurement (MWD) mainly includes the mud-pulse method, the electromagnetic method and the acoustic wave method. The main foreign MWD service companies and their products include: three MWD systems, Slim1, MWD and LWD by Anadrill Sclumberger; three MWD systems, Acuu Trak 1, Acuu Trak 2 and DMWD by Eastman Chiristensen; the DLWD MWD system by Exlog Company; two MWD systems, AGD and RGD by Halliburton; three MWD systems, slim-hole MWD, small displacement MWB and large displacement MWB by Smith Datadrill; three MWD systems, MPT, RLL, DWD/DGWD/FEED by Sperry-Sun Company; the four hole sized MWD systems by Teleco Company. The domestic MWD products include: the PMWD LWD inclinometer by Beijing Pulimen Company, and the YST-48 LWD inclinometer by Beijing Hailan Company, etc.

The down-hole data transmission technology using mud pulse (MWD) method is well developed, and many oil drilling companies in the country have the equipment and technology, which are mainly imported. The technology has certain defects in underbalanced drilling, mainly because of the gas compressibility that makes the pressure wave signals distorted, resulting in great difficulties to detect the correct signals at surface. Since the 1990s, the electromagnetic MWD technology in underbalanced drilling applications has experienced great development, and it becomes the most effective method for down-hole data real-time transmission

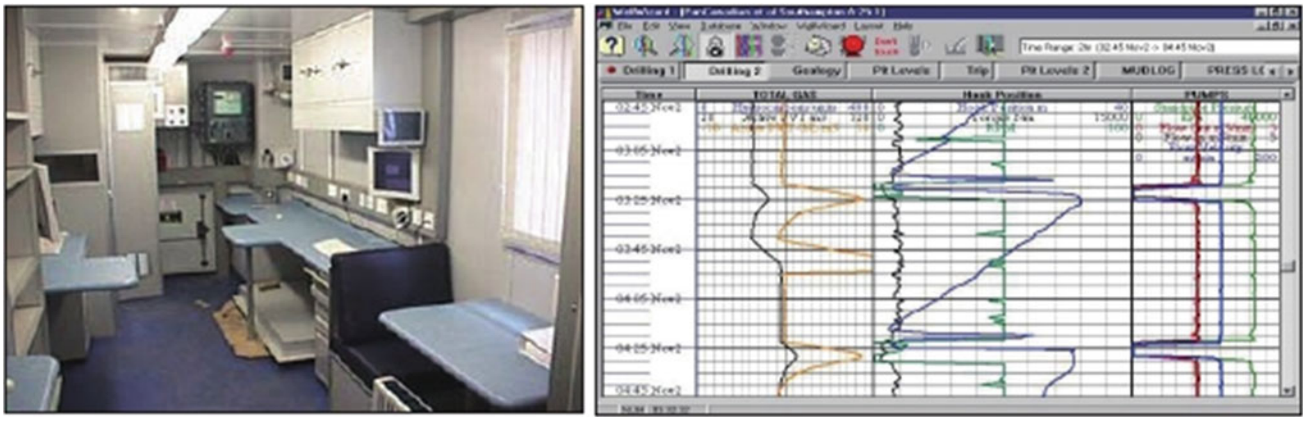

Fig. 11.2 The comprehensive logging instrument of Datalog company and the data interface

Fig. 11.3 The comprehensive logging instrument of Geoservice company and the data interface

in underbalanced drilling, which has quite a good development prospects (Fig. 11.4) because it is not restricted by deviation angle, drilling fluid (mediums) and drilling methods (rotary drilling or slide drilling).

Continental scientific drilling is a complicated system engineering, and the key to reducing the drilling costs is to drill safely and fast with high quality to decrease drilling accident rate, improve drilling efficiency and shorten drilling cycle. So the engineering and technical personnel at drill site must make and carry out the design scientifically for every aspect, and implement real-time monitoring to prevent and timely forecast the possible drilling accidents and complicated situations. Drilling process monitoring is an effective way to achieve highly efficient and safe drilling, but drilling crews in our country are still relatively weak in technical support for drilling process monitoring.

The real-time monitoring and accident diagnosis for drilling process is to identify and control the drilling process based upon the analysis of dynamic characteristics. Due to the large random disturbance of the dynamic system, the law of drilling process is difficultly described by using mathematical model. Though a single characteristic quantity can express the law of formation and development of a drilling accident, it often cannot distinguish the drilling status.

Fig. 11.4 The electromagnetic down-hole drilling parameter acquisition system from Geoservice Company

Therefore, it is required to use a variety of pattern recognition methods to make comprehensive judgments and identifications on many drilling parameters in the process of drilling. Many methods are available for pattern recognition. At present, the expert system (ES) and the artificial neural network (ANN) of the artificial intelligence (AI) for drilling real-time monitoring and accident diagnosis are most prospective, which do not need accurate mathematical models and thus are suitable for drilling process with the characteristics that experience can be relied upon, information is inadequate and imprecise.

Because most of the drill sites are in fields with inconvenient traffic, it is not easy for relevant superior department leaders or technical personnel to understand the drilling progress and conditions. Nowadays, with the continuous development of the computer network technology, the computer network and internet have been applied in all walks of life, and it is possible as well to realize remote real-time network monitoring of drilling parameters and conditions at different drill sites. At present, remote real-time monitoring system for drilling state at different drill sites in the country is still unavailable, and only DATALOG company from Canada is now conducting the research, but has not yet fully realized remote real-time monitoring based on internet.

11.2 Analysis of Data Acquisition and Processing Requirements

11.2.1 Data Acquisition System Requirements

According to the needs of full range recording and monitoring in CCSD-1 Well drilling, the main requirements for the drilling data acquisition system could be analyzed as follows:

1. **Basic data collection and drilling basic data entry**

The basic data collection mainly includes sensor nominal data and system-setting parameters, etc.; and the drilling basic data mainly includes drilling tool structure data, borehole structure data and mud pump performance data. These data are necessary for the normal work of a comprehensive logging system.

2. **Rapid acquisition of surface drilling parameters**

The data collected by the comprehensive logging system includes drilling parameters, hook parameters, mud properties and circulation parameters, and hole bottom fluids detection parameters, which basically contain all the data can be collected at surface (except drilling tool vibration).

3. **Rapid acquisition of bottom hole drilling parameters**

The bottom hole drilling parameters acquisition and real-time transmission technology are complex and difficult. Based upon the available technical conditions and the drilling needs it was determined the parameters collected included vertex angle, tool face angle, temperature and pressure; and only the non real time data transmission method could be used, namely, the method of playback after lifting the drilling tool assembly.

4. **Output of real-time data**

The output data, which include every parameter collected, are for technical personnel to monitor and analyze the drilling process. The forms of the data output mainly include data display and printing, and data curves display and printing, and the parameters of display and printing can be chosen according to needs.

5. **Drawing system of logging color map based on time and well depth**

In oil comprehensive logging, the function of color logging map drawing is essential, while in continental scientific drilling, the logging maps, which record all technical parameters of the whole construction process in detail and basically are the records of the whole construction process, should be designed according to the practical needs.

6. **Real-time data communication of the real-time batch processing mode**

In order to improve the decision-making and management level, the research on the real-time data transmission ways from well site to base data center has been conducted in oil drilling industry, and now a lot of oil fields have relatively well developed data transmission systems in wire and wireless ways. Real-time data transmission is an essential function of modern comprehensive logging system as well as the requirement of information management in drilling construction. The method of real-time data transmission in CCSD-1 Well can be selected based upon the conditions at drill site.

7. **Data-saving in the network database management system**

After being transmitted to the base, the real-time data are generally saved in the network database as the basis for future analysis and decision making. To save the mass real-time data of the continental scientific drilling in the database system can provide a good environment for the follow-up data processing and utilization.

8. **Historical data processing software system**

During the drilling construction process, it is required sometimes to make some necessary searching, processing and analysis towards the previous historical data, so various data off-line processing software should be developed according to the requirements in drilling construction.

11.2.2 Data Processing System Requirements

The requirements of the data processing system mainly include two aspects: record and monitor in the drilling process and follow-up treatment of the drilling data and comprehensive utilization of the related knowledge. The main requirements of CCSD-1 Well for the data processing system are as follows.

1. **Recording and monitoring the drilling process**

To record and monitor the drilling process is a basic requirement of the production and management in continental scientific drilling, and is a fundamental function of the comprehensive logging instruments and the requirement of the continental scientific drilling informationization as well.

2. **Abnormal data monitoring in drilling process**

Abnormal data monitoring is to monitor whether drilling parameters are abnormal, such as pump pressure, torque and drilling speed, etc. and plays the role of warning, which is mainly completed by single parameter monitoring and usually realized by computer.

3. **Data monitoring for drilling state identification**

To judge abnormalities in drilling process, basic professional knowledge combined with a number of drilling parameters are usually required to analyze and evaluate drilling condition, which provide the necessary basis for the subsequent decision. Artificial monitoring is given priority during abnormality monitoring, assisted by computer monitoring, and the job is mainly done by the technical personnel at drill site.

4. **Hole bottom fluids abnormal display monitoring**

As one of the important tasks in drilling construction, monitor of hole bottom fluids in continental scientific drilling has important scientific significance. Fluids abnormalities include hydrocarbon gases, non hydrocarbon gases and other fluids.

5. **Network monitor in drilling process to expand monitoring range and improve monitoring level**

As continental scientific drilling is a complicated project covering a wide range of advanced technologies, cybernation of drilling production management and decision-making and cybernation of drilling data processing are required as an important technical measure to improve decision-making level in drilling process and as well as an important index for modernization of continental scientific drilling.

6. **Providing software platform for subsequent software development**

In the professional computer software development, a certain software platform is usually provided for subsequent data development and utilization, and for continental scientific drilling which is rare and high-tech, data acquisition and processing system must provide a certain platform for subsequent software development to improve the system itself, and at the same time, with the development of science and technology, the subsequent software development can provide larger and better drilling data processing, management and decision-making platforms for future drilling work.

11.3 Drilling Data Acquisition System

The drilling data acquisition system for CCSD-1 Well includes two parts: surface data acquisition system and down-hole data acquisition system, the former is mainly to monitor the drilling process parameters through the surface-installed sensors, while the latter is to monitor the down-hole drilling parameters through the sensors installed in lower part of the drilling tools. The overall structure of the data acquisition system is shown in Fig. 11.5.

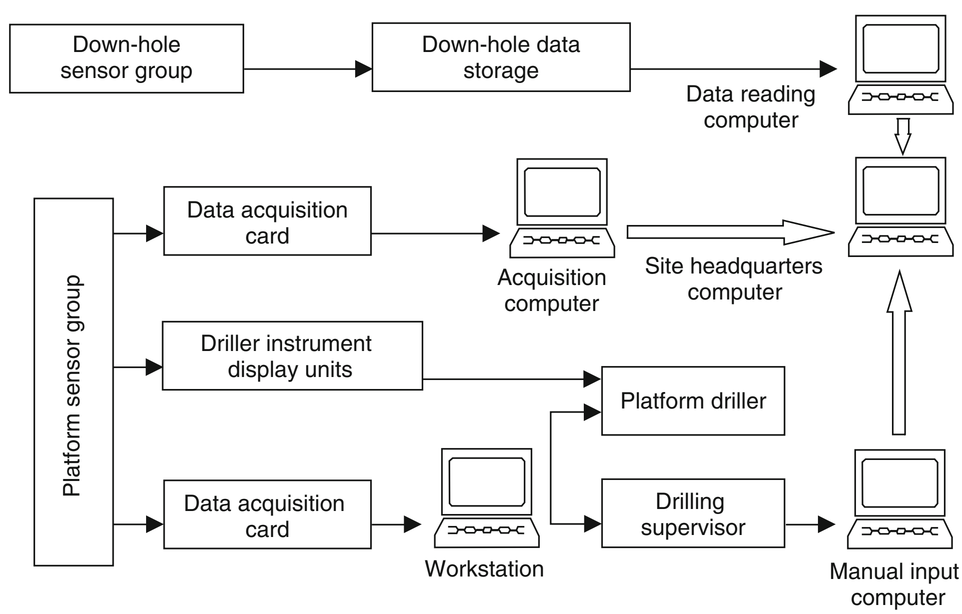

Fig. 11.5 The data acquisition system structure diagram

Fig. 11.6 The comprehensive logging instrument used in CCSD-1 well

11.3.1 Surface Drilling Data Acquisition System

SK-2000FC/C comprehensive logging instrument (Fig. 11.6) developed by Shanghai Shenkai Co. Ltd. was adopted as the surface drilling data acquisition system for CCSD-1 Well, a certain improvement and supplement were made. For example: Strengthening the manual data acquisition in the drilling supervisor office to collect some data which computer cannot collect, such as the rotary speed of dual power rotary drilling and the recorded data of drilling roundtrip; Redeveloping the software to improve the data processing and preservation function, such as to calculate the torque and drilling rate of PDM and to save the real-time data into the network database.

1. **SK-2000 FC/C comprehensive logging instrument**

SK-2000 FC/C type comprehensive logging instrument can preserve and print all the data recorded in 5 s, which is the important data source to identify the bottom-hole state and diagnose accidents, with the main technical performance as follows:

(1) Power supply

Power input: Voltage 380/220 V (+10 %, −20 %), Frequency 50 Hz

Power output: Voltage (220 + 11) V, Frequency (50 ± 1) Hz, Klirr ≯5 %

Relay time in case of power failure: Full load work ≮10 min (applicable to the power grid supply or diesel generator power supply, and instruments with overload circuit breaking, electric leakage safety protection and lacking-phase protection)

(2) Natural gas total hydrocarbon detector and component detector

Measuring range of total hydrocarbon detector: Maximum detecting concentration ~100 % (methane), Minimum detecting concentration 50 ppm

Measuring range of hydrocarbon component detector: Maximum detecting concentration ~100 % (methane), Minimum detecting concentration 30 ppm (C1–C5 can be analyzed in 3 min analysis cycle)

Measuring range of non hydrocarbon component detector: CO_2 0.2–100 %, H_2 0.01–2 %; Accuracy of measurement: 2.5 % (F.S)

(3) Sensors

Measuring unit of pump stroke rate: Measuring range 30, 60, 120, 240, 480, 960, and 1920 BPM optional; Accuracy: 1 % (F.S)

Measuring unit of rotary speed of rotary table: Measuring range 30, 60, 120, 240, 480, 960, and 1920 RPM optional; Accuracy: 1 % (F.S)

Measuring unit of rotary table torque: Measuring range 0–1.6 MPa (0–50 kN m); Accuracy: 2 % (F.S)

Measuring unit of standpipe pressure and casing pressure: Measuring range 0–40 MPa; Accuracy: 2 %

Measuring unit of hook weigh parameter: Measuring range 0–6 MPa (0–4000 kN); Accuracy: 2 %

Measuring unit of drilling fluid temperature: Measuring range 0–100 °C; Accuracy: 1 °C

Measuring unit of drilling fluid density: Measuring range 0.9–2.5 g/cm^3; Accuracy: 1 %

Measuring unit of drilling fluid conductivity: Measuring range 0–50 ms/cm; Accuracy: 2 % (F.S)

Measuring unit of drilling fluid outlet flow rate: Measuring range 0–100 % (relative flow rate); Accuracy: 5 % (F.S)

Measuring unit of drilling fluid pit volume: Measuring range 0–2 m (or according to the requirements of customer); Accuracy: 1.5 % (F.S)

Measuring unit of drawworks sensor: Measuring range 0–9999 (hook position); Accuracy: 10 mm/single rope

(4) Instruments

Carbonate analyzer;

Mudstone density measuring instrument;

Fluorescence analyzer;

Recording instrument

(5) Computer system

The full set of computer software system has the functions of acquisition, display, alarming, printing and memory, etc.

i. Data real-time acquisition procedure

As the main program for real-time acquisition while drilling and the core program for the whole set of software system, the procedure has multiple functions of real-time acquisition, calculation, multi screen display, alarming and Chinese-English free switch-over, etc., which can provide eighteen function modules and display frames (such as drilling animation, main drilling parameters, initialization of the system, sensor calibration, drilling tool management, chromatographic calibration, strip chart recording, etc.).

ii. Real-time data processing procedure

The procedure is an auxiliary procedure for real-time data acquisition program, which can generate entire-meter data files from real-time data collected by the acquisition procedure, delay the entire-meter data file, establish the open database and print the LWD real-time monitoring data tables.

iii. Off-line data processing procedure

As a processing procedure for data files generated from real-time data program, the procedure, which produces the drilling tool reports, drill bit reports, gas logging diagrams, hydraulics reports, hole deviation reports and pressure forms, etc., can edit and print the morning geological report, morning engineering report, daily geological report and water horsepower report, and input, modification, print of the geologic logging data and optimization of the drilling expert system as well.

iv. Monitor data remote transmission

In order to facilitate the geological supervisor and engineering supervisor to instruct the production at drill site, monitors 100 m away from the instrument house were respectively arranged, and the monitoring pictures could be selected according to needs.

2. Improvement on the surface data acquisition function

Data collected in drilling are generally based on time and well depth, however, for continental scientific drilling, the records based on core drilling roundtrips are also important. In the operations of statistical calculation, enquiry and storage of the data for continental scientific drilling, data calculation and processing based on the roundtrips are important as well, besides based on time and well depth, including footage drilled per roundtrip, penetration rate per roundtrip and core recovery per roundtrip, etc. According to this characteristic, in order to facilitate record, enquiry and statistics, the Excel format (as shown in Fig. 11.7) was used in manual data entry of the core drilling roundtrip records.

	A	B	C	D	E	F	G	H	I
1	MH-1C-R46回次	CCSD-MH-1C取心钻进实时记录				起始井深: 3367.52			
2	钻具组合	钻头(TGS-94)+扩孔器(TGS-09)+岩心筒(8.50-7)+扩孔器(TGS-10)+单动接头+上接头 + 液动锤(YZX-127) + 接头 (311*310)+							
3	时间 (hh:mm)	井深 (m)	进尺 (m)	钻压 (kN)	转速 (r/min)	排量 (l/s)	泵压 (MPa)	扭矩 (KN·m)	备 注
25	2003-8-6 9:30	3370.64	0.23	20.00	176	9.65	11.80	8	泵压不稳(11.5-12.5MPa)
26	2003-8-6 9:40	3370.78	0.14	20.00	176	9.65	11.80	8	泵压不稳(11.5-12.5MPa)
27	2003-8-6 9:50	3370.91	0.13	20.00	176	9.65	11.80	8	泵压不稳(11.5-12.0MPa)
28	2003-8-6 10:00	3370.99	0.08	20.00	176	9.65	12.00	8	泵压不稳(11.5-12.0MPa)
29	2003-8-6 10:10	3371.08	0.09	20.00	176	9.65	12.00	8	泵压不稳(11.5-12.0MPa)
30	2003-8-6 10:20	3371.12	0.04	20.00	176	9.65	12.00	7	泵压不稳(11.5-12.0MPa)
31	2003-8-6 10:30	3371.24	0.12	25.00	176	9.65	12.00	6.5	泵压不稳(10.5-12.0MPa)
32	2003-8-6 10:40	3371.31	0.07	25.00	176	9.65	11.00	6.5	泵压不稳(10.5-12.0MPa)
33	2003-8-6 10:50	3371.33	0.02	25.00	176	9.65	9.00	6.5	泵压下降，活动钻具
34	2003-8-6 11:00	3371.43	0.10	25.00	176	9.65	9.00	6.5	泵压不稳(9-12.0MPa)
35	2003-8-6 11:10	3371.48	0.05	25.00	176	9.65	11.00	6.5	泵压不稳(10-11.0MPa)
36	2003-8-6 11:20	3371.57	0.09	25.00	176	9.65	9.15	6.5	泵压下降
37	2003-8-6 11:30	3371.57	0.00	25.00	176	9.65	9.15	6.5	不进尺，活动钻具
38	2003-8-6 11:40	3371.62	0.05	25.00	176	9.65	9.00	6.5	泵压下降
39	2003-8-6 11:55	3371.62	0.00	25.00	176	9.65	9.00	6.5	停钻
40	2003-8-6 12:25								上提距井底8.5m遇阻(20t)倒划眼缓慢提出钻具。
41	2003-8-7 0:05								起钻,15:36-15:58保养钻机。检查钻具甩钻杆。21:
42									
43									4#岩心筒已检查（废）
44	累计钻时	回次进尺	岩心长度	平均钻压	平均转速	平均排量	平均泵压	平均扭矩	泥浆泵缸套直径
45	4.59	4.10	2.00	21.45	177.91	9.75	10.74	6.86	1#泵Φ120mm2#泵Φ120mm
46	技术指标	回次采取率	0.49	机械钻速	0.89	钻头水口	12	起钻井深	3371.62
47	回次简述:	钻进过程中泵压高、不稳，钻速慢，最终不进尺停钻。钻头（废）。下扩孔器外径157.6mm，上扩孔器外径157.7mm，岩心破碎,直径95.8mm。TGS-11#扩孔器公扣断入4#外筒							
48	现场调度:	刘玉顺（夜）李旭东（白）					驻井工程师		任海军
49									
50									

MH-1C-R45 / MH-1C-R46 / MH-1C-R47 / MH-1C-R48 / MH-1C-R49 / MH-1C-R50 / MH-1(

Fig. 11.7 The manual data entry interface

	A	B	C	D	E	F	G	H	I
1	MH-1C-R46回次	CCSD-MH-1C取心钻进实时记录				起始井深: 3367.52			
2	钻具组合	钻头(TGS-94)+扩孔器(TGS-09)+岩心筒(8.50-7)+扩孔器(TGS-10)+单动接头+上接头＋液动锤(YZX-127)＋接头（311*310)+螺							
3	时间（hh:mm）	井深（m）	进尺（m）	钻压(kN)	转速(r/min)	排量(l/s)	[illegible] (MPa)	[illegible]	备 注
4	2003-8-5 21:55	3367.52			转盘11+螺杆				钻具组合，普双7"+液动锤+螺杆
5	2003-8-6 2:45								下钻
6	2003-8-6 3:20								31"立柱(2430米)返浆，接方钻杆顶浆
7	2003-8-6 5:40								下钻
8	2003-8-6 6:45	3367.52			189	10.34	8.00	3	距井底7m遇阻，接方钻杆划眼
9	2003-8-6 6:50	3367.60	0.08	20.00	189	10.34	10.50	3	
10	2003-8-6 7:00	3367.76	0.16	20.00	189	10.34	10.50	5	
11	2003-8-6 7:10	3367.95	0.19	20.00	189	10.34	10.50	5	
12	2003-8-6 7:20	3368.09	0.14	20.00	189	10.34	11.00	6	
13	2003-8-6 7:30	3368.26	0.17	20.00	189	10.34	11.00	6	
14	2003-8-6 7:40	3368.41	0.15	20.00	189	10.34	11.00	6	
15	2003-8-6 7:50	3368.69	0.28	20.00	170	9.31	10.50	8	
16	2003-8-6 8:00	3368.94	0.25	20.00	170	9.31	10.50	8	

Fig. 11.8 Manual data entry and the recording mode

In the design of the data entry interface, a drilling roundtrip was recorded as one electronic working table, at the upper part of the interface was mainly recorded the basic data of a roundtrip (current roundtrip number, bottom hole assembly and initial depth), at the lower part was mainly for statistical data and important descriptions of this drilling roundtrip, and in the intermediate part was for the main drilling parameters and abnormities (recorded every 10 min). Some parameters to which comprehensive logging instruments could not collect were manually calculated and input, such as the rotary speed of dual power rotary drilling, abnormal phenomena happened during tripping (pulling out and running in), and the distance to the hole bottom where slacking-off was encountered and reaming-down was needed, etc. (Fig. 11.8).

In the redevelopment of the software system of the comprehensive logging instrument, functions of parameter calculation, data processing and storage of the downhole power drilling tool were strengthened in the aspect of data acquisition. The function of parameter calculation mainly included the calculations of the rotary speed and torque of PDM, and calculation of drilling rate, etc. The functions of data processing and storage mainly included the display of historical data and the playback of the curves, and the storage of real-time data into the network drilling database, etc. The software structure is shown in Fig. 11.9.

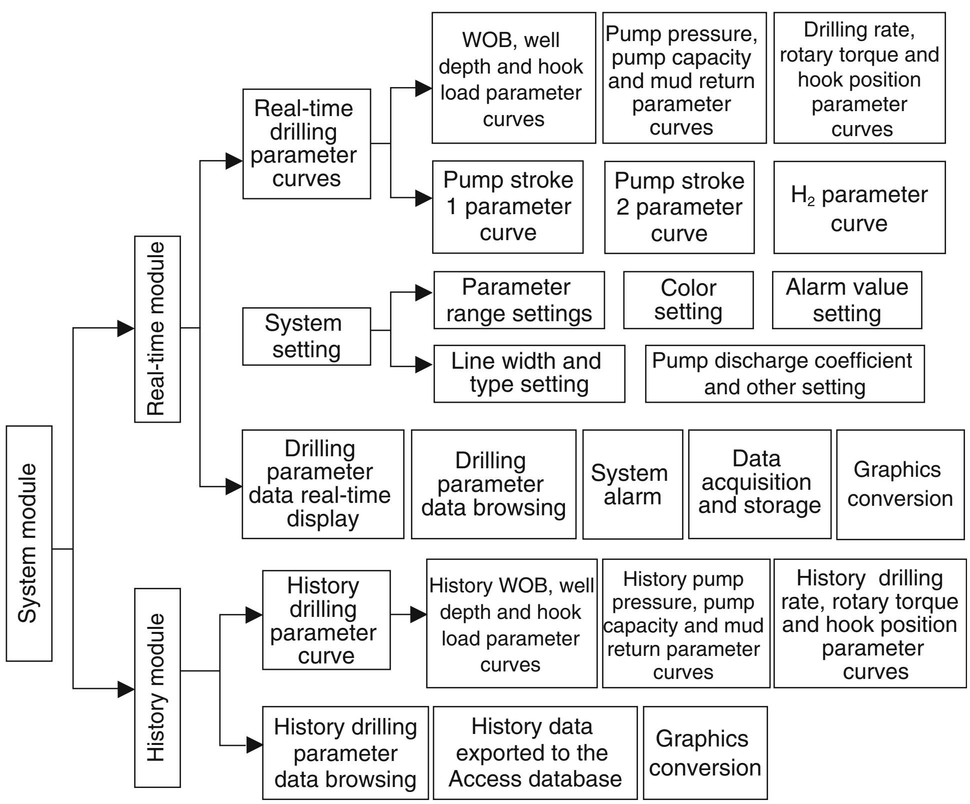

Fig. 11.9 Structure of the redeveloped software

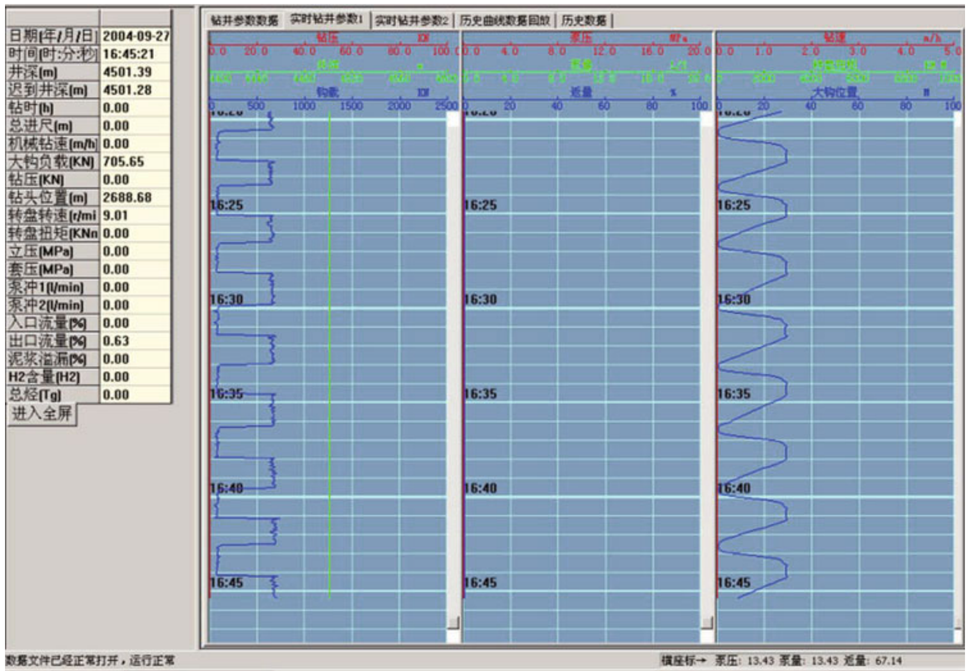

Fig. 11.10 The real-time data displaying interface

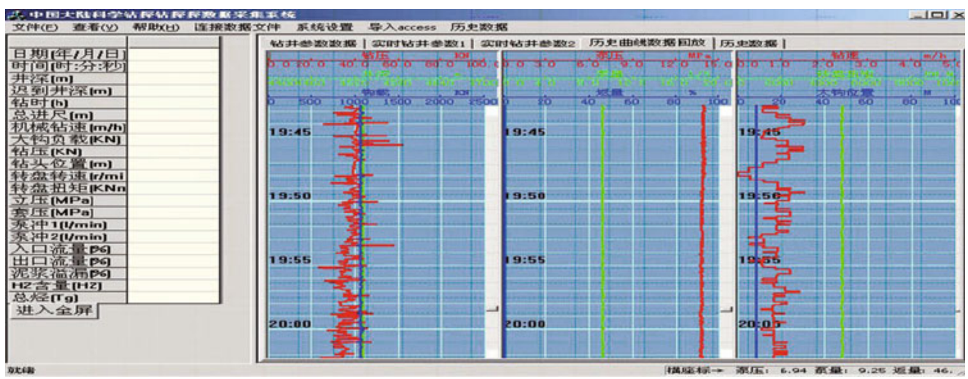

Fig. 11.11 The playback interface of historical data curves

The functions of the redeveloped drilling data software include the following:

i. Function of data real-time display. After startup, the software enters the interface as shown in Fig. 11.10. On the left of the main interface, commonly used drilling parameters are real-time displayed in the drilling data list, and on the right drilling curves are real-time displayed, rolling upwards with the lapse of time.

ii. Functions of drilling data auto-saving and management. The system automatically saves the daily drilling data, with a data file formatted as the CCSD file per day, which was encrypted and opened only by the system.

iii. Function of system setting. The system settings include five parts: setting for drilling parameter curve coordinate range; setting for color; setting for line width and type; setting for alarming value; setting for pump flow coefficient and other settings;

iv. Full-screen function;

v. Function of graph saving. Graphs of drilling curves are saved in BMP format files;

vi. Function of data export. The CCSD format data in the system can be exported into path files, to be easily processed and utilized;

vii. Function of browsing historical data and curves. Historical data and curves can be browsed (Fig. 11.11).

11.3.2 Down-Hole Drilling Data Acquisition System

The information of bottom hole condition in continental scientific drilling contains the data which reflect the working state of drilling, economic indexes of drilling technology, drilling parameters and the information about the bottom hole drilling tool assembly. Therefore, monitoring these data information is of important practical significance.

On the premise of satisfying the requirements of continental scientific drilling, the design of the bottom hole drilling parameter data acquisition system should be of an economical, practical, convenient and high-precision technical scheme, and at the same time the technical feasibility and practicability should be fully considered. According to the importance of drilling parameters and bottom hole drilling tool structure, the down hole data acquisition system was researched and developed, the parameters monitored by which contained vertex angle, tool face angle, temperature and mud pressure, etc.; Detection instruments could be installed either on the overshot assembly of the wireline core drilling tool or on conventional core drilling tool; The collected data were stored in the memory of the instruments, which could be connected with a computer when pulled out of the borehole, with the data read into the computer for processing. China University of Geosciences (Wuhan), entrusted by the CCSD Centre, developed DPMA-1 downhole parameter detection playback acquisition system (Figs. 11.12 and 11.13) for detection-while-drilling of vertex angle, tool face angle, and pressure and temperature of down hole drilling fluid.

The main technical indexes:

Vertex Angle: 0–45°, with error ≤0.5°

Pressure: 0–50 MPa, with error ≤0.5 MPa

Temperature: 0 to +150 °C, with error ≤0.5 °C

Face Angle: 0–360°, with error <5°

Impact resistance: 10 g

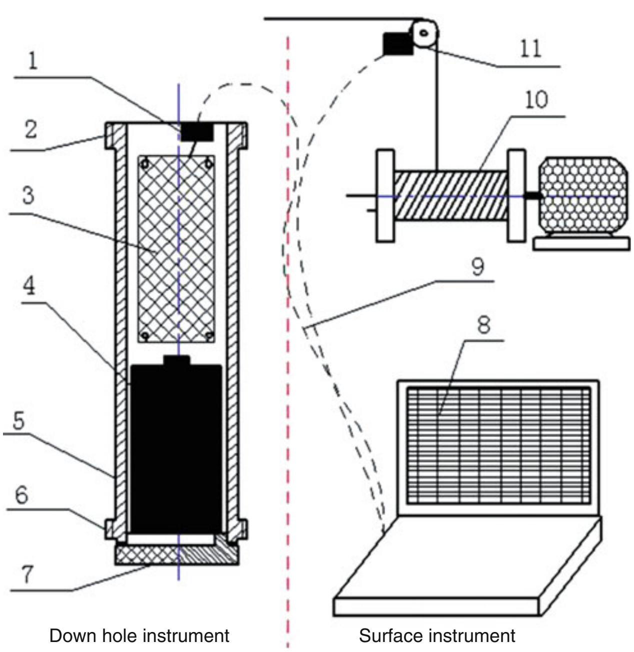

Fig. 11.12 Structure of down-hole drilling data acquisition system. *1* Playback interface. *2*, *6* Connecting thread of tension ring. *3* Double PCB. *4* Battery. *5* Instrument outer barrel. *7* End cover. *8* Computer. *9* Data playback cable. *10* Drawworks. *11* Depth synchronous recorder

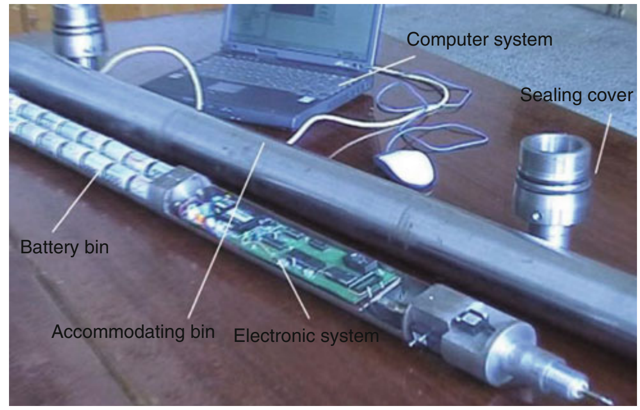

Fig. 11.13 Assembly of down-hole drilling data acquisition system

Heat resistance: 0 to +85 °C

Sealing: 50 MPa above

Data record capacity is 32 KB, in case that sampling time is set for 5 s, 8 bytes of four sets of data (2 sets of vertex angle, pressure, and temperature data) are stored each time, the memory can work for 22 h.

The main technical indexes of the hole parameters storage and fishing instrument of the auxiliary wireline fishing spear:

The instrument has the function of automatically save the data of down-hole temperature, pressure and vertex angle, with the storage capacity expanded to 64 KB;

The instrument has the function of playback the recorded data at surface, thus can make continuous measurement of multiple points.

Vertex angle test range and precision: 0–45°, with error ≤5°; temperature test range: 0–150 °C, with error ≤0.5 °C

Pressure test range: 0–50 MPa, with error ≤0.5 MPa

Impact resistance: 10 g

Sampling interval was adjustable and sampling time could be set as four groups of data could be saved each time (2 groups of vertex angle, pressure and temperature data).

Size of instrument barrel (detection tube) size: ϕ 60 × 1500 mm

The down-hole drilling data acquisition system was tested for five times at the drill site of CCSD-1 Well and the tests showed that the tested parameters of the DPMA-1 down-hole drilling parameter automatic recording and playback device were complete. The device could not only detect the borehole temperature and pressure changes (especially the dynamic changes), and provide the most direct reference basis for mud property designs, but also could judge the working conditions of the down-hole tool and the on-way resistance of mud during circulation, etc. based upon the mud dynamic and static pressure changes respectively measured by changing the installation positions of the instrument.

The tests obtained four parameters, i.e., pressure and temperature of the mud at bottom hole, vertex angle and tool

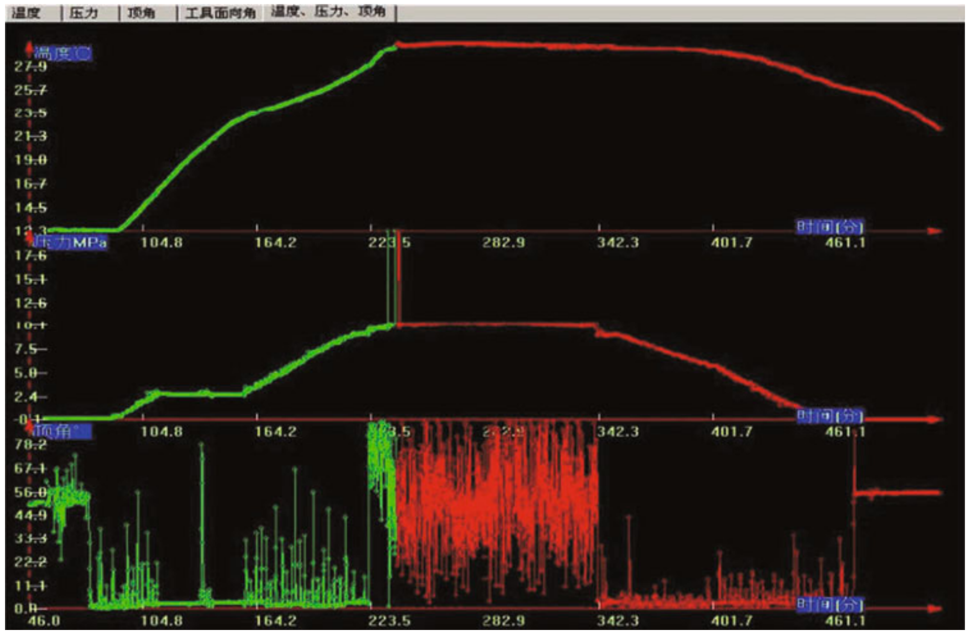

Fig. 11.14 Data playback curves collected by the down-hole drilling parameter acquisition system

face angle during drilling in CCSD-1 Well. And the test results were accurate with repeatability and the instrument performed stably and reliably, which came up to the requirements of design and got a successful result. The playback curves are shown in Fig. 11.14.

11.4 Drilling Data Processing System

The real-time data collected by the continental scientific drilling data acquisition system contain omnibearing information in drilling process, which must be analyzed and processed to raise the monitoring level in drilling and decision making level in construction. The monitoring in drilling process is carried on according to the difficulty degrees. Firstly, the setting limited value of an important single parameter should be monitored, which can play a warning role when change takes place in drilling process, and drilling engineers should pay attention to the downhole changes; Secondly, when downhole conditions change, drilling technicians must analyze and judge the changes of the parameters based upon the previous experience and relevant theoretical knowledge or with the aid of the computer software, evaluate the downhole conditions, prevent and timely forecast the possible complicated status and drilling accidents. So, the strategy of monitor in drilling process is from easy to difficult, from single parameter monitoring to multiple parameters monitoring, as shown in Fig. 11.15.

11.4.1 Single Parameter Monitoring

Single parameter monitor includes two parts, real-time monitoring (including well-flushing and redressing) in drilling process and real-time monitoring in tripping process. Single parameter monitoring can be implemented by computer or manual work, which mainly monitor the abnormal conditions during drilling processes as an early warning.

The main contents of the monitoring in drilling process include display of pump working state (including the starting state and the pump stroke number, etc.); display of drilling fluid performance (including mud density parameters, etc.); real-time calculation of hydraulic parameters (including equivalent circulating density, etc.); display of pump pressure change (including nozzle block and nozzle piercement, judgment of drilling tool piercement, etc.); display of net variation of total pool volume (judgment of well kick, lost-circulation, etc.); display of torque change (judgment of drill bit failure or drilling tool broken, etc.); display of bit weight (bit weight overrun and drill string not well braked); display

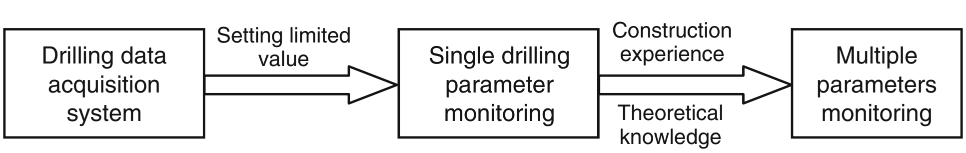

Fig. 11.15 Monitoring in drilling process

of hanging weight (main basis for judging over pull or tight pull) and display of drilling speed (rock formation changes, bit wear, down-hole drilling tool broken, etc.).

The main contents of the monitoring in tripping process include monitor of tripping speed (pressure fluctuation); monitor of the rest time of drill string in open hole section; monitor of hook load change; monitor of net variation of total pool volume, etc.

11.4.2 Comprehensive Monitoring

Comprehensive monitoring denotes the monitor of drilling process dynamics, mainly the monitor of drilling process, based on the changes of two or more parameters. The comprehensive monitoring of a number of parameters can accurately judge the down-hole states or accidents happened, etc. Comprehensive monitoring is mainly completed by engineering and technical personnel, who then make an analysis and form a judgment on the parameter changes based upon their theoretical knowledge and practical experiences.

The main contents of the comprehensive monitoring include: the changes of hook position and hook weight are used to monitor the free-fall or not-well-braked drill string; the changes of drilling rate and pump pressure are used to monitor the working status of PDM and hydro-hammer and condition of core blockage; the changes of drilling rate, bit weight, pump pressure and torque are used to monitor tool broken and bit wear; the changes of total mud pool volume and inlet and outlet flow are used to monitor well kick and lost circulation.

Computer network can be used to expand the limits of drilling process monitoring, so as to improve the monitoring level. According to the monitoring technological level, the monitor of drilling process in continental scientific drilling project can be divided into two levels: one is on-site monitoring, which makes preliminary data analysis and processing to provide necessary information for drilling supervisors and engineers for decision-making; the other one is the base monitoring, which redevelops the data and make deep analysis and processing with the aid of the related data processing software, and supplies more detailed information for the related technical personnel and leaders. Both the on- site monitoring and the base monitoring are multi-point monitoring, while the content and level of the latter are higher than those of the former. The structure of the drilling process monitoring system for CCSD-1 Well is illustrated in Fig. 11.16.

The on-site monitoring is more real-time, and is completed by drillers, drilling engineers and drilling supervisors. The base monitoring is less real-time, and is completed by senior technical personnel. During the drilling process monitoring of CCSD-1 Well, the whole drilling process monitoring system ran well.

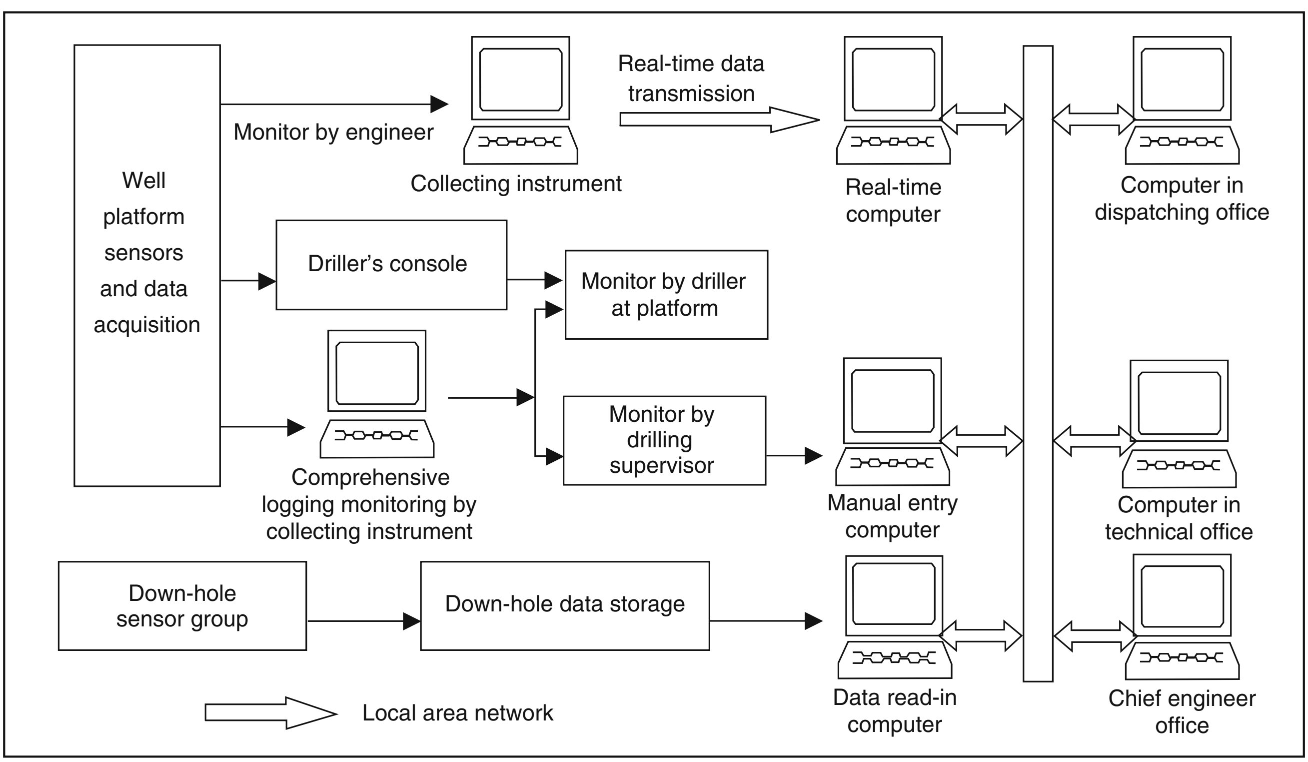

Fig. 11.16 Structure of drilling process monitoring system

11.4.3 Case History

Figure 11.17 shows the logging curves of ϕ 157/311.1 mm normal reaming drilling on May 9th, 2002, from which can be found the pipe connection process and time.

Figure 11.18 illustrates the drilling parameter curves before pulling out the broken lower reaming shell in core drilling on February 10th, 2002, from the curves it can be found that torque didn't change and penetration rate was very low when drilling torque was reduced and bit weight increased.

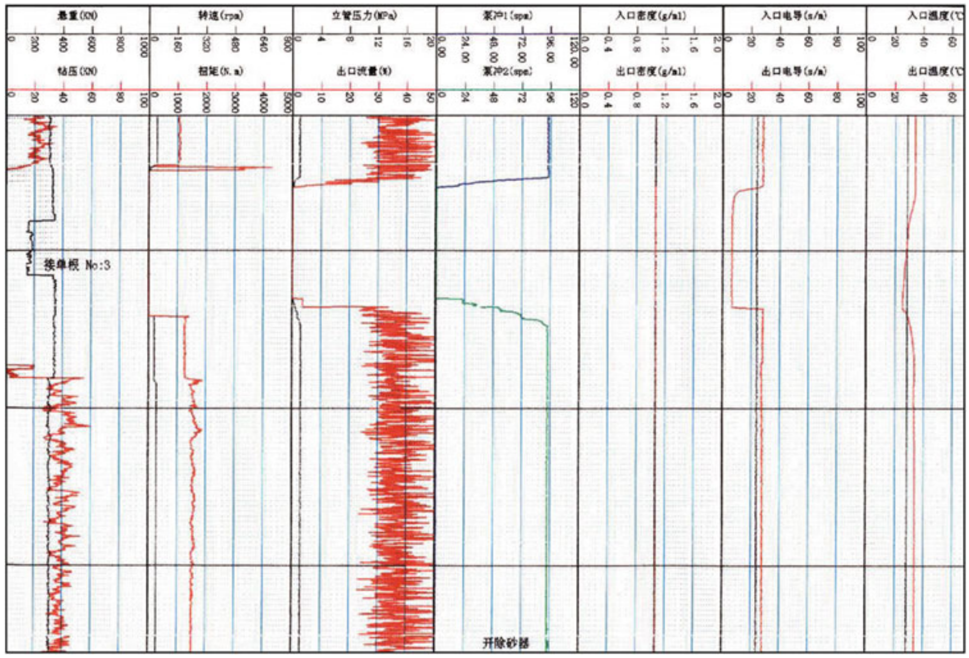

Fig. 11.17 Drilling parameter curves of 157/311.1 mm reaming drilling

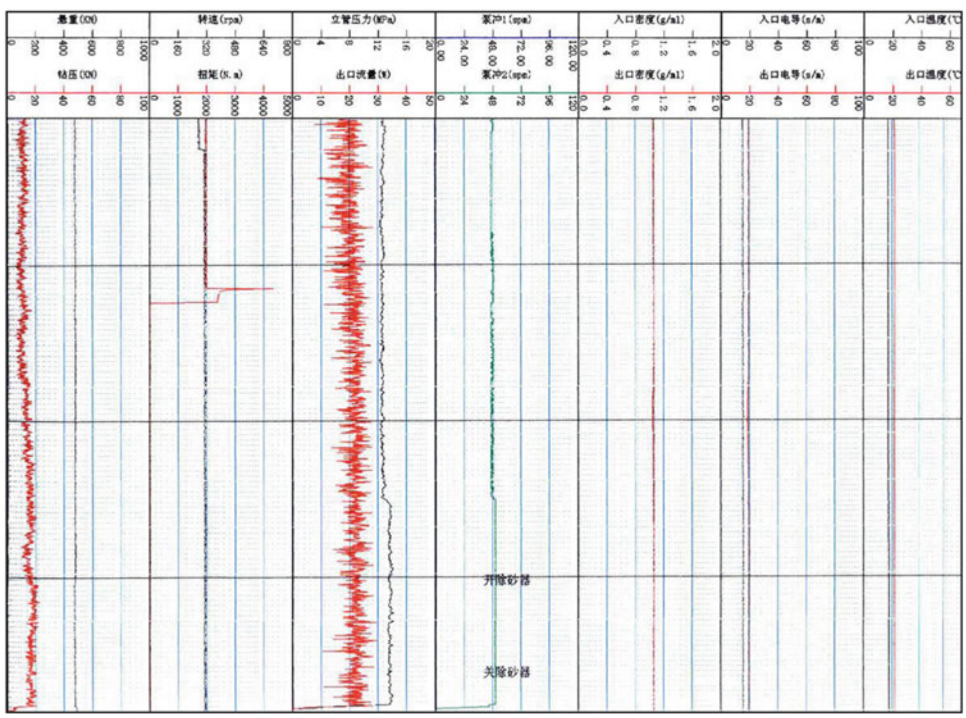

Fig. 11.18 Drilling parameter curves before pulling out the broken lower reaming shell

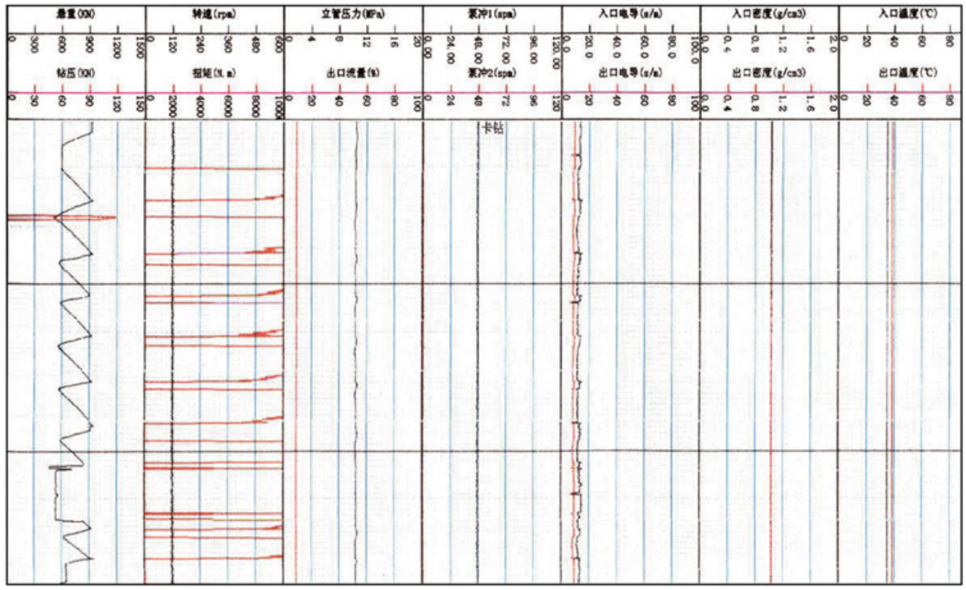

Fig. 11.19 Logging curves of the settlement of the drill pipe sticking accident occurred during deviation correction drilling

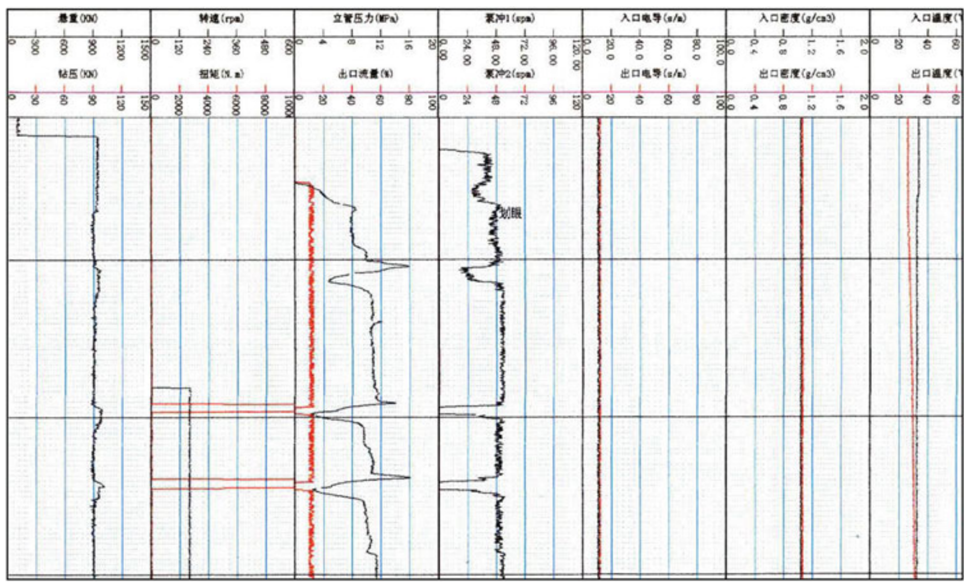

Fig. 11.20 Logging curves of redressing process

Figure 11.19 indicates the logging curves when the drill pipe sticking accident occurred during the deviation correction drilling on May 18th, 2003, in which the process of accident settlement was clearly recorded.

Figure 11.20 shows the logging curves of redressing process before core drilling when drilling tool was run down to the hole bottom on September 24th, 2003, in which was recorded the change of the drilling parameters

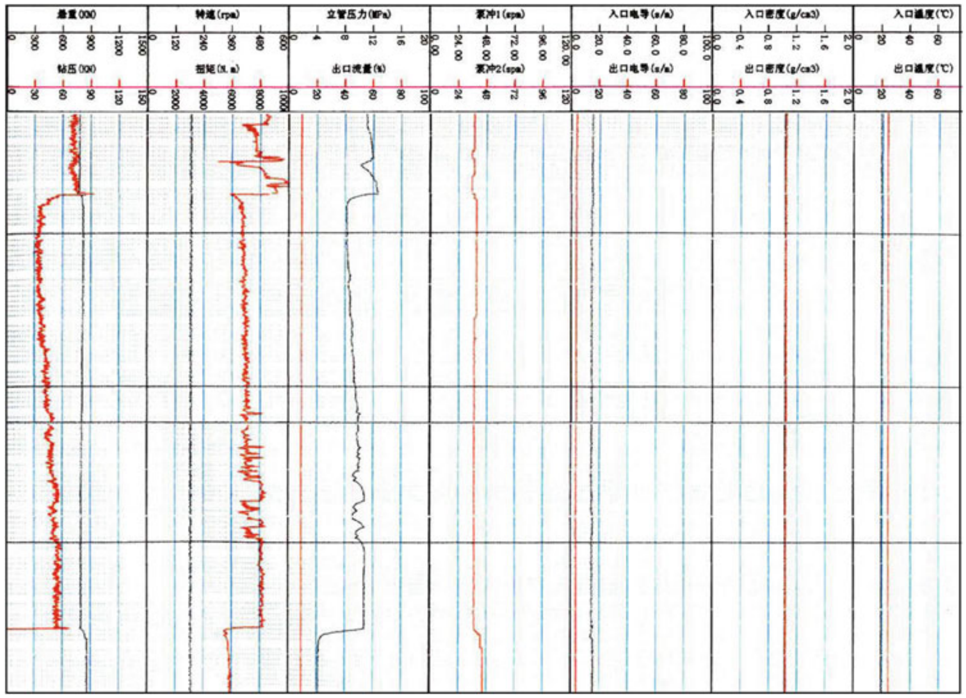

Fig. 11.21 Logging curves when drill bit steel body fractured during core drilling

when bit bouncing occurred during PDM hydro-hammer core drilling.

Figure 11.21 indicates the last logging curves when drill bit steel body fractured during core drilling on February 6th, 2003, from the curves it can be found that the penetration rate was very low, and the torque and pump pressure increased when bit weight was increased.