Establishment of Experimental Calibrating Facilities for Oil-Air-Water Three-phase Flow

Zhang Jianjun [1]; Sun Difei [1]; Shi Huining [1]; Yang Yongxiang [1]; Li Xu [2]; Wang Chi [2]
1—Production Technology Research Institute of Huabei Oil Corporation, 062552, Renqiu
2—National Institute of Metrology of China,100013,Beijing

Abstract: Technical specifications, Principle, work procedure, structural features, function, test procedure and analysis of uncertainty for oil-air-water three-phase experimental facility are introduced. According to the specifications, it is found that the establishment of the device is successful and some experience for further work are accumulated.

Keywords: Three-phase Flow, Experimental Facility

1.Overview

The oil-air-water three-phase flow simulation experimental device is mainly to simulate the flowing type, flowing state, flow of three-phase water-well oil, air and water flowing as well as mixture ratio of them, to analyze the flowing characteristic of under-well fluid as well as for research, development and test of the production and test instruments, is the basic experimental device for developing the research in productive measuring technology as well as oil-air-water three-phase flow research involved in oil field development, also the calibrating facilities for under-well and ground testing metrological instrument.

2.Technical Requirement

(1) Functions can be realized

Simulating (5½in), (7in) declining well , horizontal well and water flooding well;

Calibrating the underwell flowmeter, moisture meter, densitometer, etc. in production measuring well, graduating the explaining chart desk for production well logging materials, etc;

Providing multi-phase flow experimental environment and conditions for developing the dynamic monitoring and research for production as well as under-well testing instruments;

Calibrating various ground water flooding flowmeter;

(2) Technical specifications

Flow range for three-phase flow:

that for oil: 0.1～600m^3/d

Flow range for water phase: 0.6～600m^3/d

Flow range for air phase: 30～2000m^3/d

Total flow (max. at oil water phase) 1800m^3/d

Flow range for single phase:

Flow range for oil phase: 0.004～25m^3/h

Flow range for water phase: 0.004～50m^3/h

Flow range for air phase: 1.25～85 m^3/h

Operation media: kerosene, water, air

Accuracy of standard flowmeter: accumulated oil flow 0.2%; instantaneous flow 0.5%

Accumulated water flow 0.2%; instantaneous flow 0.5%

Accumulated air flow 0.5%;

instantaneous flow 1%

Offline calibrating facilities: electronic balance (better than 0.05%)

Bell prover (better than 0.2%)

Water-content range: 0～100%

Steadiness: Oil and water 0.2%

Air 1.0%

Pressure-stabilizing way: by container

Working temperature: normal temperature

Operation pressure: （0.2～0.6）MPa

Pressure-withstanding capability of system: 1.6MPa

Height of the simulating well hole: 12m

3. Operation Principle and Process Flow

The three-phase flow facility consists of the following: oil-water-air three-phase media system, metering & inspecting and controlling system, tiltable simulating well-hole system.

At present, most of oil-air-water 3-phase flowing facilities in the international world will first measure by separate phase, then mix into three-phase fluid mixture for 3-phase flow testing. The advantage of this way is that it can accurately measure the sum of flow from single phases and effectively control the mixing proportion of 3-phase flow. For the 3-phase flow media after experiment, after passing the air-fluid separator and oil-water separator, the air will be discharged outdoors, water and oil will return to the oil box or water box respectively, then pumped to the experimenting pipe for testing, and they will be used repeatedly by circulating.

As for the process flow of the calibrating facility for oil-air-water three-phase flow, please refer to fig.1 attached. For oil-air-water mixed phase flowing, first the air is separated in the separator, then the oil and water are separated and go into oil box and water box respectively.

The water and kerosene will be pumped out from their storage box respectively, go into single-phase fluid experimental pipe or mixed-phase experimental pipeline through pressure-stabilizing can, filter, standard flowmeter and flow-regulating valve. The air will be buffered preliminarily in the air accumulator via air filter, air compressor, so as to remove pulse flow brought about by air compressor, hence form up the 1st stage of stable air source. Then the air will go into pressure-regulating container through the self-operated regulating valve, on the pressure-regulating container, it can have a set of automatic pressure-regulating system, here it forms up the 2nd stage of stable air source. Finally, the air goes into the pressure-stabilizing container, and forms up stable air source before the standard meter, so as to guarantee the steadiness of flow and accurate measurement of the flowmeter. Passing the standard flowmeter and flow-regulating valve, the air will enter into the air-flow experimental pipeline or mixed-phase experimental pipeline.

In the mixed-phase experimental pipeline, the oil and water will first be mixed by the oil-water mixer, then go into the air-liquid mixer with the compressed air, and form up oil-air-water three-phase mixed fluid, then enter into 3-phase flow experimental pipeline or tiltable simulating well-hole section. The three-phase fluid of oil, air and water can also go directly into the experimental pipeline or tiltable simulating well-hole section without mixing. The 3-phase fluid out from the experimental pipeline will enter into the oil-air-water separator.

In the facility, the flow of single phase for oil, water and air will be metered by their own standard flowmeter. The standard flowmeter will be calibrated by single-phase on-line calibrating facility; for oil and water, weighing way will be used, and bell-prover is used for the air facility.

4.Technical Requirements on Main Components

(1) Water pool and oil bath

All fluid in the system will be put in the pool and bath when no experiment is made. The level variation in water pool is $\Delta h \leqslant$ 200mm.The liquid pool shall have some tolerance, the upper and lower tolerance are about 200mm respectively. The distance from the water-absorbing head from water-pool's wall shall be more than 300mm, and the distance from pump's absorber to the liquid surface shall be $\geqslant$7D (D is inner diameter of the pump's absorbing pipe). Between pump and pump's water absorber, it shall have enough distance or be isolated by wall. The box body shall be equipped with: overflowing weir with a flowrate of v ≤ 0.015m/s; contamination-holding structure and contamination-coagulating bath; level meter and automatic water inlet valve; filtering mesh.

(2) Pressure-stabilizing container

In order to guarantee that the flow of liquid is steady and the data about the standard flow given by the facility is reliable, the system is required to provide a steady constant-pressure water head. This is the steadiness of the facility. It mainly has two factors influencing the steadiness of flow, one is the pressure fluctuation of high-pressure water head, it is low-frequency pulse; another is flow-resistance change due to local resistance loss in the pipe (angle head and valve, etc.), it is high-frequency pulse. In this system, air-filled pressure-stabilizing container i.e. the compressibility of air is used to remove the high-frequency pulse brought about by the pump, and frequency-converting pump is used to remove the low-frequency pulse.

Blow-off opening shall be furnished at lower part of the pressure-stabilizing can, and pressure gage and over-pressure protection valve are equipped at upper part. Overflowing board is used to isolate the inlet from outlet, and 3 layers of separating boards are furnished at the inlet side.

(3) Separator

The oil-air-water separator uses a horizontal separating can, its inner structure uses stainless steel filler, and oil-water separating area is increased. The separating way is the natural precipitating way by density difference between oil and water. Technical specifications are: air content in liquid:≤1.0%; water content in kerosene at outlet: ≤ 0.5%; oil content in sewage at outlet: ≤ 300mg/L; liquid content in air at outlet: ≤ 0.05g/Nm 3 ; kerosene 100μm : bubble removal rate ≥95%; oil content in water pool ≥0.5%; water content in oil bath ≤ 0.5%; material of separating can: 0Cr18Ni9;

(4) Mixer

Consisting of two stages i.e. oil-water mixing and air-liquid mixing one.

5.Inspecting the Equipment

All equipment, such as offline calibrating facilities i.e. electronic balance, reverser, bell prover, etc. as well as the online calibrating facility as mass flowmeter shall have passed inspection and reached to the designed specifications.

6. Analysis on Uncertainness of the Facility

(1) Liquid flow facility

As for analysis on the measuring uncertainness of the liquid flow facility, please refer to the following table.

Uncertainness in measuring for the liquid flow facility				
S/N	Source	Standard uncertainness (%)	Coefficient of sensitivity	Contribution
1	Electronic balance	0.025	1	0.025
2	Correction of liquid density	0.29	-0.0013	0.000
3	Correction of air density	0.9	0.0011	0.001
4	Correction of density of the standard balance weight	0.074	1.7×10^{-4}	0.000
5	Reverser	0.02	1	0.02
6	Timer	0.004	1	0.004
Resultant standard uncertainness: 0.032%; expanded uncertainness: ≤0.06%				

Therefore, the expanded uncertainness of liquid flow facility by way of static mass is 0.06%. It can calibrate liquid mass flowmeter of 0.2%.

(2) Gas flow facility

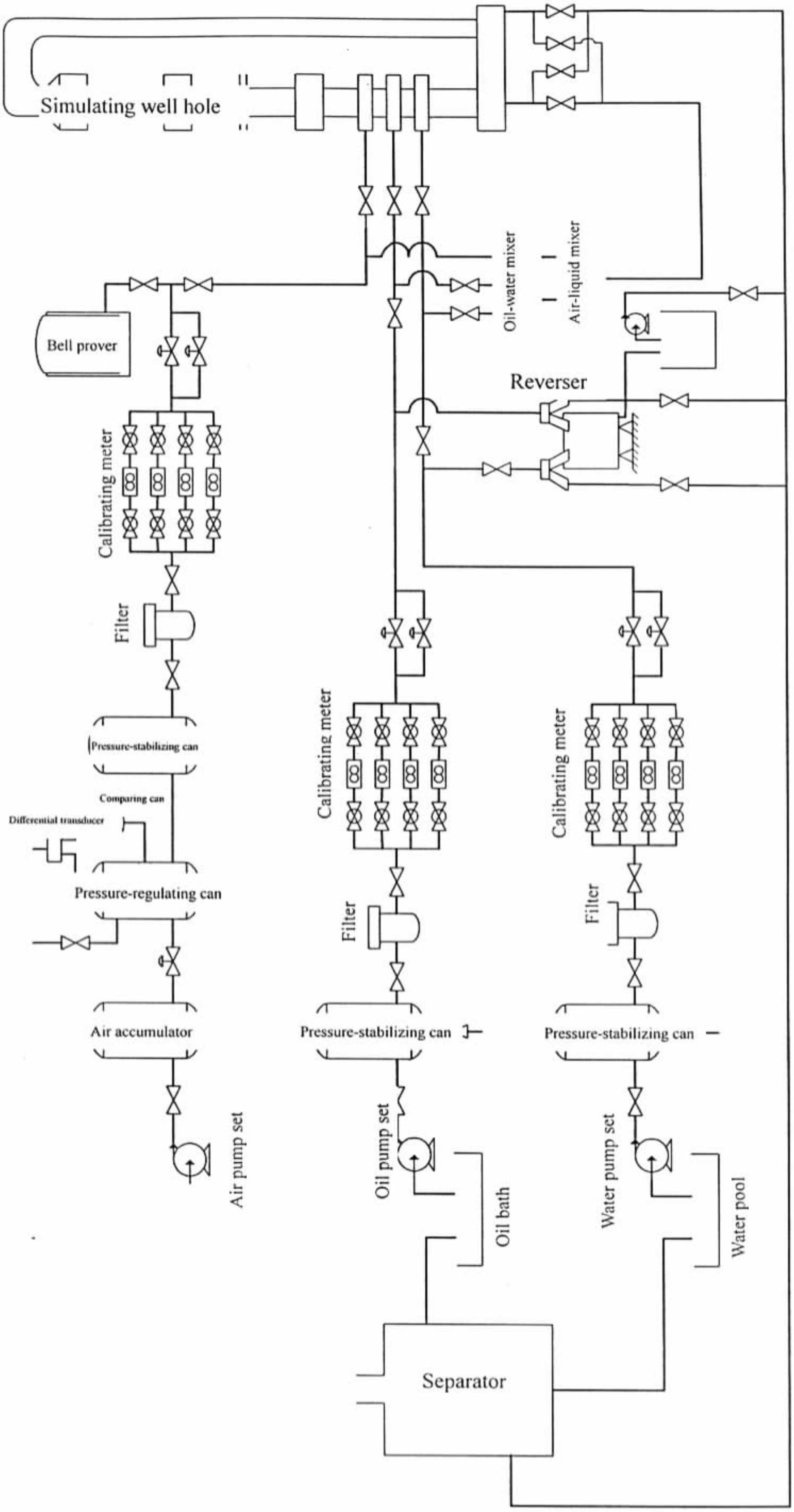
As for analysis on the measuring uncertainness of the gas flow facility, please refer to the following table.

Uncertainness in measuring for the gas flow facility				
S/N	Source	Standard uncertainness (%)	Coefficient of sensitivity	Contribution
1	Bell prover	0.1	1	0.1
2	Pressure correction	0.035	1	0.14
3	Temperature correction	0.029	1	0.12
Resultant standard uncertainness: 0.11%; expanded uncertainness: ≤0.22%				

Therefore, the expanded uncertainness of bell-prover flow facility is 0.22%. It can calibrate air flowmeter of 0.5%.

7.Conclusion

The facility has a good performance and has reached to the designed specifications, can meet the application requirement. It can be used for inspecting the flow and analyzing the performance.



Simulating well hole
Oil-water mixer
Air-liquid mixer
Bell prover
Reverser
Calibrating meter
Filter
Pressure-stabilizing can
Comparing can
Differential transducer
Pressure-regulating can
Air accumulator
Air pump set
Calibrating meter
Filter
Pressure-stabilizing can
Oil pump set
Oil bath
Calibrating meter
Filter
Pressure-stabilizing can
Water pump set
Water pool
Separator