AADE-25-NTCE-032

Innovative fluid systems for temporary zonal isolation and further enhanced removal to increase hydrocarbon productivity

Juan Esteban, Carlos Gamboa, Ginna Rosero and Daniela Serrano, Baker Hughes

Abstract

A workover operation was planned in a gas well to increase the hydrocarbon production by perforating new potential intervals in a cased hole completion. To perform the operation was required to temporarily isolate a perforated production interval with a formation pressure of 1,650 psi to perform a perforation job of a deeper interval with greater production potential and higher formation pressure of 3,860 psi.

The solution to temporary isolate the initial perforations was provided by pumping an innovative magnesia-based phase transitioning thixotropic fluid, activated with temperature for high strength set and able to be dissolved by using an enhanced removal fluid to restore the gas productivity.

Under normal conditions the isolation would have been done by pumping a cement plug, causing irremediable damage to the formation with the need to re-perforate and stimulate the interval in order to recover the production (with no certainty). Those conditions would have added cost and time to the operation.

The enhanced removal fluid homogeneously dissolved the temporary isolation fluid and increased the productivity of the initial perforated interval. Laboratory tests were carried out for this application based on downhole temperature and breakthrough time obtaining excellent results in increasing gas production of the interval.

Introduction

To maintain or restore the productivity of a well some workover operations after the drilling of the well are needed. In cased holes the plugging of current production intervals and perforating new holes are designed to increase the oil and/or gas production.

The permanent abandonment of old intervals and perforations of higher pay zones in the well are common operations; but, for special workovers that requires only temporary abandonment and perforations of lower pay zones in the well, a new technology was required.

Advanced fluid systems were developed to address those challenging workover conditions and enabled temporary isolation of the production zone without the use of mechanical plugs. After perforating and testing the lower zone in the well with higher production pressures the efficiency of the temporary isolation fluid was proved as no pressure transmission was observed through the isolated interval in the upper part of the well.

After concluding the workover operations, the isolation fluid was removed completely with the enhanced removal fluid that improved the natural gas production of the interval by increasing 50% of gas production versus the initial tests.

The operational program, design, and procedures were based on the well schematic, completion string, and production conditions of the well prior to the application.

Laboratory tests were done to evaluate the performance of the zonal isolation fluid and to a novel removal fluid. Both fluids can be customized depending on the characteristic of the application, downhole conditions, and rock formation properties (ZhaoZheng et al., 2016).

In this paper the authors will present the details of the field application design, laboratory test, and proven results for the efficiency of both developed fluids for the workover operation.

Isolation Fluid

Isolation fluid is a high compressive strength magnesia-based material designed to mitigate severe or total loss of circulation. The system provides a tailored alternative for plugging or abandonment operations where acid solubility is critical or where there is a risk of gas migration. It can be used for zonal isolation, casing or liner repair, or environmentally sensitive operations (Toro et al., 2023).

The design of the isolation pill was developed with considering the static and circulating temperatures during the pumping and positioning process. The objective was to ensure sufficient thickening and setting time to safely pull the pumping string to a secure point (Coveney et al., 1996). To validate the characteristics of the pill, consistency tests (Figure 1) and ultrasonic cement analysis (UCA) tests (Figure 2) were conducted. considering the test results the proposed design enables a maximum of two hours of operational activity at 140°F, which is the time required to carry out the application process.

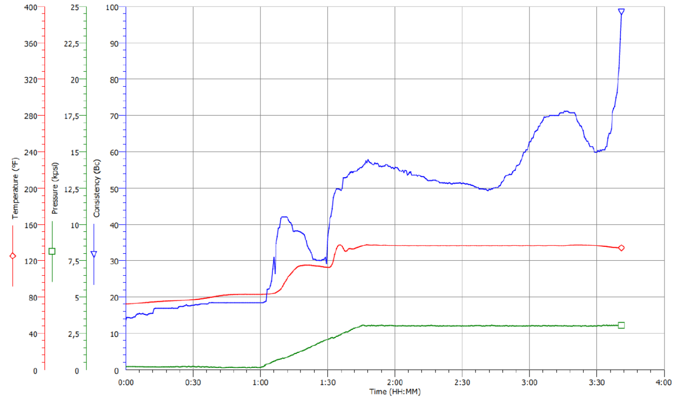

Figure 1. Isolation fluids pill consistency test at 140°F.

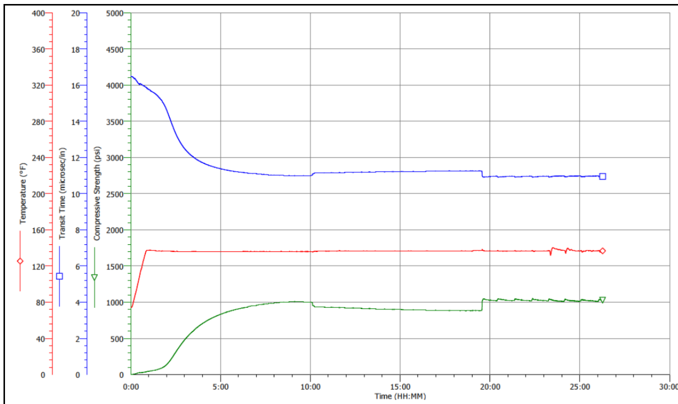

Figure 2. Isolation fluids pill UCA test at 140°F.

Zonal Isolation Process

An isolation fluid with a density of 12.5 lb/gal was proposed to isolate the perforations in the intermediate section of the well. The system exhibits rheological characteristics of a thixotropic fluid forming a high gel structure under static conditions (Quissak et al., 2022). The control fluid in the well was a sodium formate brine with a density of 8.4 lb/gal. The segregation of the pill is evaluated under static conditions demonstrating precipitation of the pill by the control fluid due to the difference in density between them (Garcia et al., 2020).

The positioning of a high viscosity suspension pill with a density of 12.5 lb/gal was proposed and evaluated, granting a favorable result for the application. The Isolation pill was kept in suspension for the needed five hours to ensure setting. The properties of the suspension pill are detailed in Table 1.

A total of 26 bbl of suspension pill was positioned from the bottom of the well (9,067 ft) to the theoretical base of the isolation pill (7,557 ft). The placement of the suspension pill was executed in two stages to bypass contact and flow of the pill through the perforation zone, which could potentially compromise the integrity of the formation due to pill's high content of solids. Figure 3 illustrates the process.

A volume of 17 bbl of isolation pill was positioned in front of zone "A" (Figure 4) following a displacement plan that included pumping 10 bbl of viscous pills in front and behind the isolation fluid and balancing with control fluid.

Table 1. Suspension pill properties.

Property	Unit	Value
Density	ppg	12.5
Rheology temperature	°F	120
600 RPM reading	Dial reading	94
300 RPM reading	Dial reading	67
200 RPM reading	Dial reading	56
100 RPM reading	Dial reading	42
6 RPM reading	Dial reading	16
3 RPM reading	Dial reading	15
Plastic Viscosity	cP	27
Yield Point	lb/100 ft^2	40
Yield Strength	lb/100 ft^2	14
Gel 10 seconds	lb/100 ft^2	14
Gel 10 minutes	lb/100 ft^2	19
Gel 30 minutes	lb/100 ft^2	24
pH	-	8.5

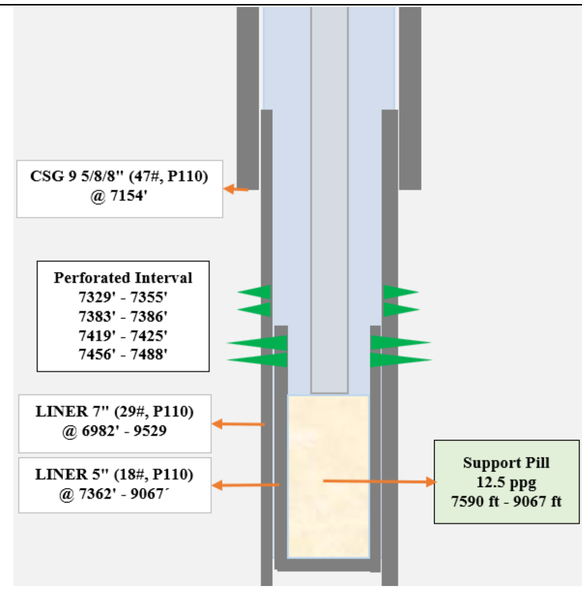

Figure 3. 12.5 ppg viscous pill to support Isolation pill.

The pump string was then pulled to 6,800 ft (200 ft above the theoretical top of the isolation pill). Then, the annular blowout preventer (BOP) was closed, and the isolation pill was bullheaded through zone "A" perforations with 250 psi for 10 minutes. Next, the pill was allowed to set for four hours, which was twice the design time that was required for the thickening time (Figure 4).

Drilling and Cleaning of Isolation Pill

The clean out process of the setting pill was performed in two stages. The first stage had the objective of clean the pill right at the seven inches liner using a bottom hole assembly (BHA) with six inches taper mill and seven inches scraper. The cleaning string was run down to 7,071 ft where the top of the setting pill was found.

One of the main operational challenges for the application was the limitation of the workover surface equipment to rotate the cleaning string and mill the setting pill. For this reason, the cleaning operation was carried out by percussion drilling with a flow rate of six bbl/min and applying a maximum weight to the bit of 2,000 lb. This cleaning was carried out to the top of the five inches liner at 7,362 ft.

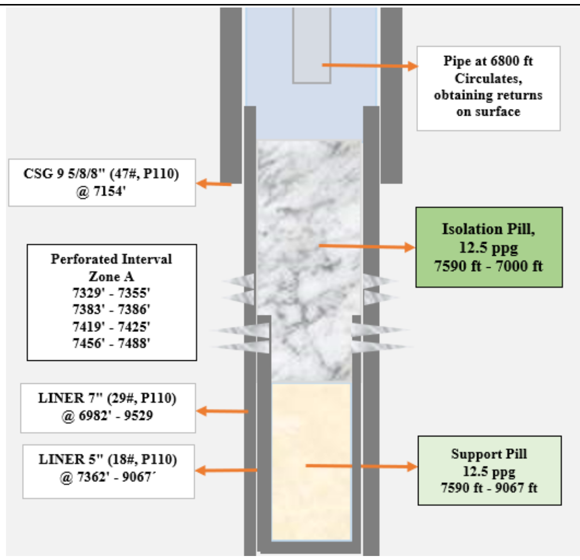

Figure 4. 12.5 ppg Isolation pill (7,590 ft – 7,000 ft). Close annular and bullheaded Isolation fluid through formation (250 psi x 10 min).

At 7,362 ft a pressure test was performed with 1,000 psi for 10 minutes, with successful results. This confirmed a positive seal in the Zone “A” perforations located in the seven inches liner (Figure 5). The seven inches liner cleanout BHA was pulled out from the well at 7,362 ft to the surface.

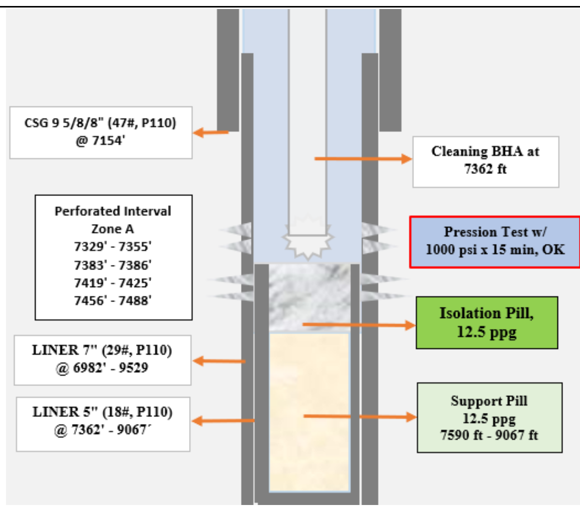

Figure 5. Clean out seven inches liner. Pressure test for sealing validation.

The second stage consisted of drilling and cleaning the setting pill from the five inches liner, run a BHA with 4.5 inches PDC drill bit, and place five inches liner scraper to 7,362 ft. The drilling of the isolation pill from the five inches liner located at 7,362 - 7,516 ft was achievable with 4.5 bbl/min flow rate of water and 2,000 lb weight on bit.

A pressure test was performed with 750 psi for 15 minutes to the five inches liner in order to evaluate the perforation’s isolation in zone “A”. The test results were a constant pressure which confirmed the functionality of the isolation pill over the entire section (Figure 6).

Confirming the perforation isolation with a pressure test of the zone “A” was key to the application. The achieved equivalent pressure increased from 1,650 psi to 4,200 psi.

The formation pressure of zone “B” and zone “E” was 3,860 psi. If no effective isolation is achieved in the sensitive formation, the control fluid could cause fractures and fluid loss through zone "A".

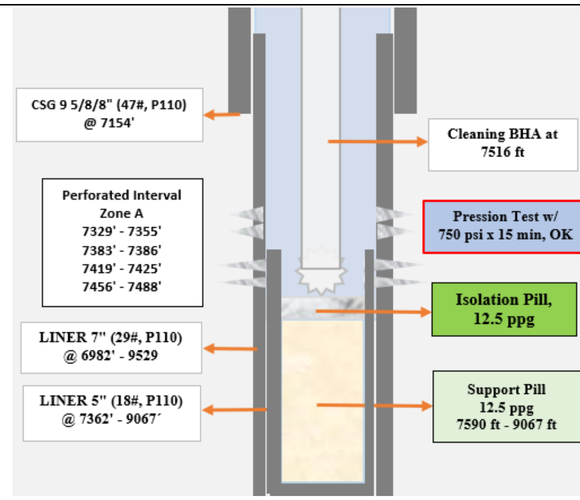

Figure 6. Clean out five inches liner. Pressure test for sealing validation.

After pressure tests the drilling continued, and cleaning isolation pill set in five inches liner from 7,516 ft to 7,590 ft with 4.5 bbl/min flow rate and 2,000 lb weight on bit. The cleaning BHA was run down to 9,067 ft and circulated until the well was displaced with control fluid.

Enhanced Removal Application

Following the isolation of zone “A” workover interventions were conducted in zones “B” and “E” to create perforations. Once these zones were perforated and brought into production, the completion string was deployed to isolate the lower zones, enabling intervention in zone “A” for the removal of the isolation system. The removal process involved the application of an enhanced removal technique, using a specially formulated chemical solution primarily composed of a chelating agent and brine among other components. This solution reacts in a controlled manner with the material and does generate aggressive corrosion to the tubulars.

The benefit of using the isolation system plus the enhanced remover is the high solubility, reaching 100% removal after four hours of contact with the treatment. Representing an important advantage because most treatments used on the market reach maximum solubility values of 92% (Figure 8). Additionally, the stimulation of zone “A” was performed to mitigate formation damage incurred during well drilling, enhancing the zone's productivity.

A critical aspect of this operation was the precise control of the reaction time between the remover and the isolation system. A piston-type sweep was used to ensure the complete removal of the material along the entire perforated interval; thereby, facilitating optimal contribution from the formation. This application method also ensured effective well control and risk mitigation of potential gas kick.

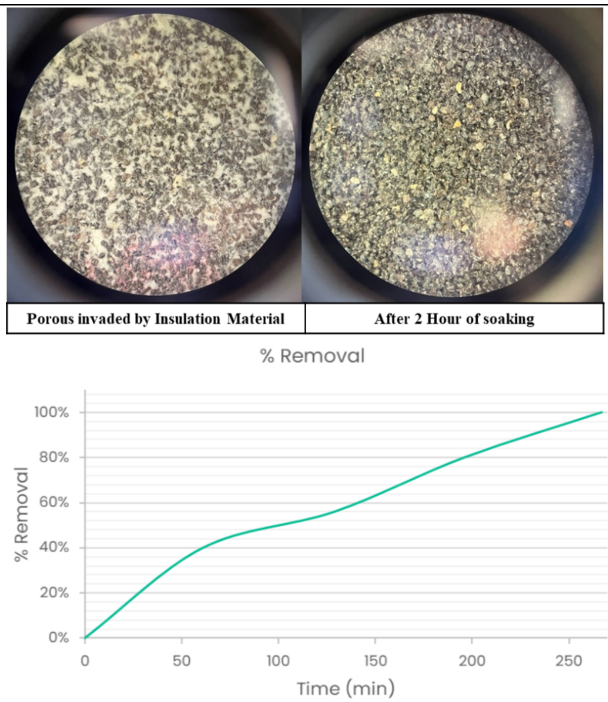

Figure 8. Material removal. Lab testing at 140°F.

With the completion assembly in place and two slick-lines positioned directly in front of the perforations (at 7,300 ft – 7,363 ft interval), coiled tubing was employed to displace and optimize the injection of treatment fluids (Figure 9). The operation began with the displacement of the spacer fluid to perform the injection of the enhanced remover. The remover was forced through the completion string and into the perforations at a rate of one bbl/min (Figure 10). It is noteworthy that the injection pressures during this stage were approximately 50% lower than those observed during the initial injectivity test, particularly during the first eight minutes of operation.

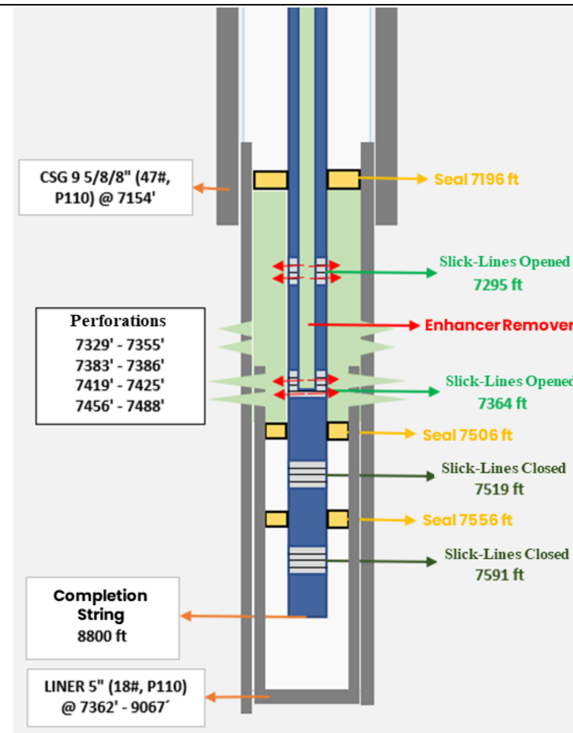

Figure 9. Remover positioning by coil tubing.

The remover was left in the well for 10 hours while the wellhead pressure was continuously monitored. The pressure was recorded at three psi at seven hours, increasing to 60 psi at 9.5 hours and reaching 210 psi at 10.5 hours. The well was filled with control brine and closed after the soaking period. After one hour, the pressure stabilized and began to rise at a ratio of 162 psi/hour.

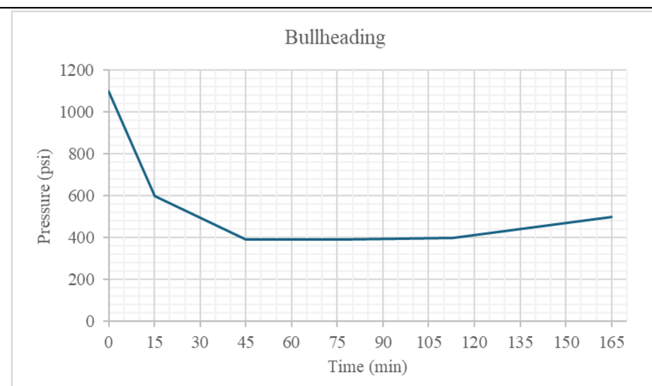

Figure 10. Enhanced removal bullheading process.

Finally, the well was reopened and aligned with surface measurement equipment to conduct production monitoring. The results on surface demonstrated an additional gas flow rate of 50% production over initial production, indicating successful remotion of isolation pill of zone "A" and near wellbore stimulation increasing in the hydrocarbon productivity of the well by the enhanced removal system.

Conclusions

The efficiency of the customized applications of the isolation and enhanced removal system is attributable to the isolation of the perforations in the zone "A", enabling the operator to perforate in zone "B" and zone "E".

The removal of the isolation system with the enhanced removal recovered the initial production of the zone "A" (1,487 MMSCF), and also helped to improve productivity, which increased 50%.

The isolation system isolated the perforations in zone "A" and helped to increase the equivalent pressure needed for the client to intervene in the lower zones of the well.

The isolation system proved to be an effective alternative when restrictions or limitations of having a drilling rig or workover equipment.

The isolation pill could be drilled with low flow rates and percussion without compromising the seal generated at the perforations.

The components of the implemented enhanced removal system and its cleaning mechanism increased production by 50% in zone "A", in comparison to the values recorded prior to isolation (Garayev et al., 2024). The increment may be attributed to the removal of calcareous scale which had not been identified by the client and was removed with the enhancer removal (Muhammad et al., 2018).

Acknowledgments

To all Baker Hughes R&D and engineering team involved in the development of these innovative fluids systems.

Nomenclature

UCA	=	*Ultrasonic cement analysis*
PPG	=	*Pounds per gallon*
RPM	=	*Revolutions per minute*
BBL	=	*Oil US barrel*
BOP	=	*Blowout preventer*
BHA	=	*Bottom Hole Assembly*
WOB	=	*Weight on bit*
WO	=	*Workover*

References

Almubarak, Tariq, Jun Hong Ng, and Hisham Nasr-El-Din. 2017. "Oilfield Scale Removal by Chelating Agents: An Aminopolycarboxylic Acids Review." SPE Western Regional Meeting, Bakersfield, California, April 2017. SPE-185636-MS. https://onepetro.org/SPEWRM/proceedings-abstract/17WRM/4-17WRM/195947

Coveney, P. V., P. Fletcher, and T. L. Hughes. 1996. "Using Artificial Neural Networks to Predict the Quality and Performance of Oil-Field Cements". AI Magazine 17 (4):41.

Garayev, M., Adoga, C., Trim, S., and P. Brand. "Subsea Pelican Oil Field Scale Management and Production Enhancement." Paper presented at the SPE Oilfield Scale Symposium, Aberdeen, Scotland, UK, June 2024. doi: https://doi.org/10.2118/218720-MS

Garcia, German, Dumont, Hadrien, and Tunde Akindipe. "Gravity-Assisted Wellbore Segregation During Hydrocarbon Sampling in Low-Permeability Rock." Paper presented at the SPWLA 61st Annual Logging Symposium, Virtual Online Webinar, June 2020. https://doi.org/10.30632/SPWLA-5055

Muhammad Shahzad Kamal, Ibnelwaleed Hussein, Mohamed Mahmoud, Abdullah S. Sultan, Mohammed A.S. Saad. "Oilfield scale formation and chemical removal: A review". Journal of Petroleum Science and Engineering, Volume 171, 2018, Pages 127-139, ISSN 0920-4105. https://doi.org/10.1016/j.petrol.2018.07.037.

Parkinson, M., T. Munk, J. Brookley, A. Caetano, M. Albuquerque, D. Cohen, and M. Reekie. 2010. "Stimulation of Multilayered High-Carbonate-Content Sandstone Formations in West Africa Using Chelant-Based Fluids and Mechanical Diversion." SPE International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana, USA, February 2010. SPE-128043-MS. https://onepetro.org/SPEFD/proceedings-abstract/10FD/10FD/SPE-128043-MS/106579

Quissak, Felipe. Mesa, Sebastian. Toro, Carlos. 2022. "Successful application of Thixotropic LCM Technology for zonal isolation in Magdalena Medio Basin Colombia", AADE-22-FTCE-050, AADE Fluids Technical Conference April 19-20, 2022. https://www.aade.org/application/files/1516/5237/6406/AADE-22-FTCE-050_-_Mesa_et_al.pdf

Toro, Carlos, Velasquez, Eliana, Avellaneda, John, Olivella, Luis Carlos, and Edgar Luna. "Successful Application of Multipurpose Thixotropic Technology for Lost Circulation, Wellbore Strengthening through Directional Tools in Well Control Events in Colombia." Paper presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, October 2023. doi: https://doi.org/10.2118/214790-MS

Wolf, C. A. de, E. Bang, A. Bouwman, W. Braun, E. De Oliveira, and H. Nasr.El-Din. 2014. "Evaluation of Environmentally Friendly Chelating Agents for Applications in the Oil and Gas Industry." SPE International Symposium and Exhibition on Formation Damage Control, SPE-185636-MS. https://onepetro.org/SPEFD/proceedings-abstract/14FD/14FD/D011S001R006/212831

ZhaoZheng, Wang. Romero, Henry. Ramos, Fausto. 2016. "Viability study of a system for filtercake remotion in pay zone of oil wells", Enfoque UTE V.7-N.2, Jun. 2016, pp. 1-9. http://scielo.senescyt.gob.ec/scielo.php?script=sci_arttext&pid=S1390-65422016000200001