EFFECTIVE UTILIZATION OF CO2 FOR OIL AND GAS FIELD DEVELOPMENT IN VIETNAM

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ABSTRACT: In southern Vietnam, there has continued to increase number of industrial plants, which are becoming the large amount of CO2 emission sources. Some offshore CO2 gas fields have already been developed by separating CO2 from the produced gas and more offshore CO2 contained gas fields are waiting for the development. Through these activities, CO2 emission will be more and more increased and its immediate reduction has to be considered from environmental protection point of view. It is apparent to take this action in quicker manner. JOGMEC and VPI have been cooperated to tackle this issue through the joint studies since 2007. CO2 EOR application to the oil field(s) will increase oil production as well as contributing CO2 sequestration by transporting CO2 from industrial plants or CO2 contained gas field. In addition, unique Japan technology of Gas To Liquid (JAPAN-GTL) can handle CO2 directly to produce liquid from produced gas including CO2 without separating CO2. An integrated design of CO2 related development is overviewed in the paper.

INTRODUCTION

Japan Oil, Gas and Metals National Corporation (JOGMEC) specializes in technology related to oil and natural gas exploration and development as shown in Fig.1, and deploys its expertise to find solutions to technical problems at oil and gas fields operated by Japanese companies. JOGMEC also collaborates on projects globally, having technical partnerships with oil- and gas-producing countries. JOGMEC develops the basic and advanced technologies necessary for these solutions, and provide the technologies and the latest technical information to private industry.

From 2007, JOGMEC, Vietnam Oil and Gas Group (PVN) and Vietnam Petroleum Institute (VPI) have been cooperated in the technical studies intensively for EOR and Gas utilization technologies. Those technologies are aimed to develop the oil and gas fields considering the reduction of CO2 emission. The paper separately focuses on the CO2 EOR and GTL, however, the integration is considered since both technologies can be combined well for the effective utilization of CO2.

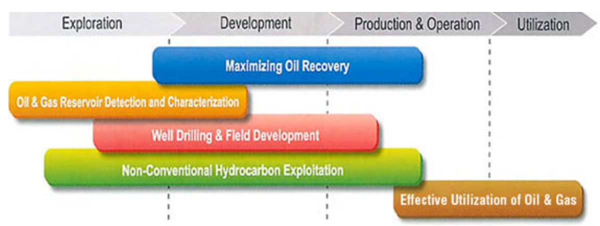

Figure 1 JOGME Current Technology Area

FEASIBILITY STUDY ON CO2 EOR APPLICATION TO OFFSHORE VIETNAM OIL FIELD

In one of the oil field producing from sandstone reservoir, JOGMEC started CO2 EOR study in 2007 as the joint study among JOGMEC, PVN (VPI) and JX Nippon Oil & Gas Exploration Corporation and completed in 2010.

The target reservoir is characterized as a thin-layered sandstone with the depth of 2,100 mss and 50m gross thickness. Structure map is shown in Figure 2. Average reservoir permeability is in the range of several tens of md with wide variety from several md to thousands md. Average porosity is about 25%. Initial reservoir pressure is 3,100 psi with the oil gravity of 38°API. Since water injection has been started step by step, the reservoir pressure has not been increased field-wide yet and the current reservoir pressure has depleted in the range of 2,000 - 2,500 psi. The field operator is planning to expand the number of water injectors to sweep oil and to increase reservoir pressure for preparing possible gas flooding (i.e. CO_2 EOR).

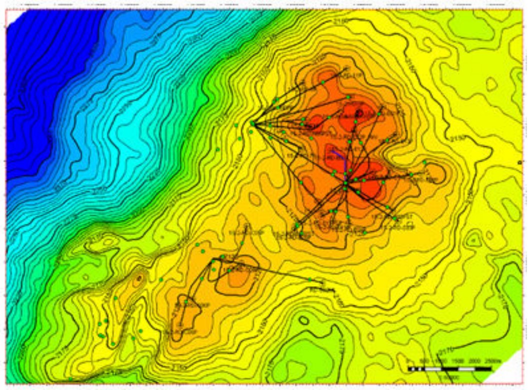

Figure 2 Target Reservoir Map

The success of CO_2 EOR project relies on the following several key issues;

- Reliable Reservoir Simulation Model
- MMP (Minimum Miscible Pressure) and Core Flood Test
- Evaluation of Field Incremental Recovery Factor (Vertical and areal sweep efficiency)
- CO_2 injection related cost and economics

The above four technical issues have been studied in detail and described below.

Reliable Reservoir Simulation Model:

Black oil (Oil – Gas – Water immiscible system) reservoir simulation model has been constructed by upscaling the geological model. After tuning the reservoir parameters, mainly permeability distribution has been reviewed and modified by the careful investigation of porosity-permeability correlation, reasonable history matching has been achieved. Figure 3 shows the geological model in the representative layer and Figure 4 shows the history matching results.

MMP (Minimum Miscible Pressure) and Core Flood Test:

A series of laboratory study was conducted to obtain reservoir Oil-CO_2 interaction function by using recombined oil from fresh surface samples. Conventional PVT test, slim tube test, solubility swelling test, core flood test and interfacial tension measurement were conducted mainly at the Technology Research Center (TRC) of JOGMEC.

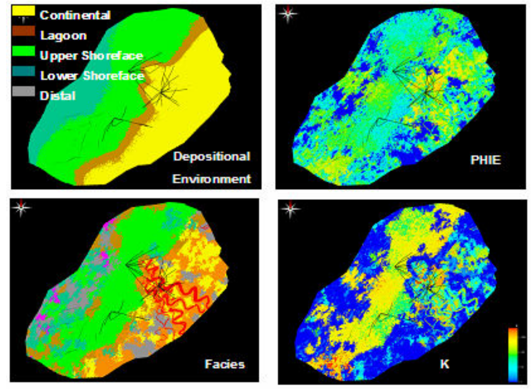

Figure 3 Geological Model

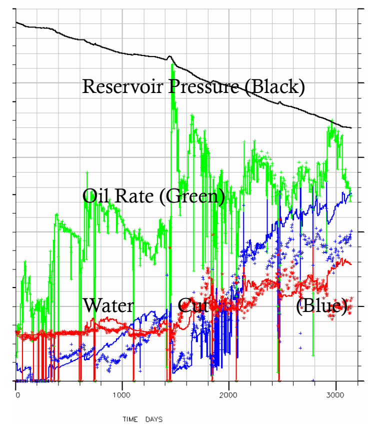

Figure 4 History Matching Results

- Slim tube test for MMP Measurement

Slim tube is composed of the long pipe (4.6 mm diameter and 12.2 m length) with packed beads. Porosity is around 37% with 9 Darcy of Permeability (Refer to Figure 5). Before injecting CO_2, slim tube is filled with reservoir fluid. By maintaining the target pressure, the recovery factor is plotted at 1.2 pore volume of CO_2 injection as shown in Figure 6. In addition, the fluid flow condition is visually monitored at the sight cell. By measuring oil recovery at several points of pressure, pressure-oil recovery cross plot is created as shown in Figure 6. At the pressure above MMP, oil recovery does not increase any more as miscible condition achieved. The MMP is estimated by the bending point in Figure 6.

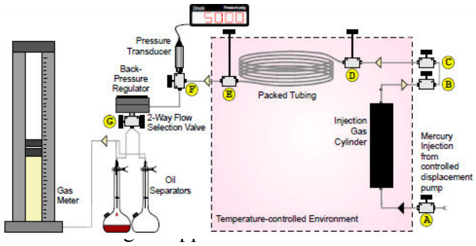

Figure 5 Apparatus of slim tube Test

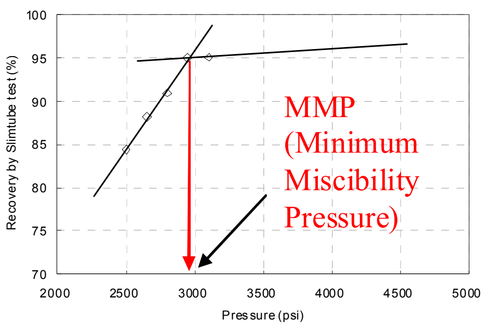

Figure 6 Slim tube Test Results

Separately from slim tube test, Interfacial Tension between reservoir fluid and CO2 was measured to compare MMP. Slim tube test results and Interfacial tension (IFT) measurements were plotted in the same figure as a function of the pressure in Figure 7, which indicated the similar MMP. By this comparison, the MMP is believed to be more reliable.

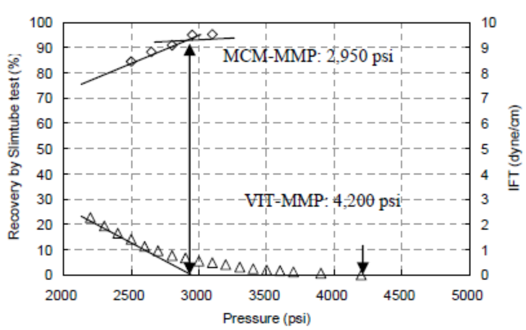

Figure 7 Comparison of slim tube Test and IFT Measurement in terms of Minimum Miscibility Pressure (MMP) estimation.

- Core flood test

In order to estimate the recovery factor at the heterogeneous reservoir rock, the the core sample taken from the field has been flooded by CO2 after careful examination of the cores by X-ray CT scan (to examine whether fracture or damage inside is existing or not). Core flood test by CO2 was conducted from the top of the composite core with the injection rate of 0.1 cc/min in order to minimize the effect of the gravity. The results showed more than 85 % of core scale (micro-scale) recovery factor by CO2 injection (93.1% by secondary mode and 88.6% by tertiary mode). By this study, more realistic oil recovery efficiency has been measured, but still at the core scale evaluation.

Evaluation of Field Incremental Recovery Factor (Vertical and areal sweep efficiency)

In order to evaluate incremental recovery factor by CO2 injection in this field, we have to rely on the reservoir simulation technique including reservoir fluid-CO2 physics. This reservoir fluid-CO2 compositional modeling technique is called as Equation Of State (EOS) Modeling. For the EOS modeling, the Peng-Robinson EOS method (1978) was used.

After the parameter tuning, the EOS simulation results successfully matched with experimental data of constant composition expansion, differential liberation, separator test, viscosity measurement, CO2 swelling test, and CO2 slim tube test. For the CO2 slim tube test, comparison between the measured and the calculated is shown in Figure 8; oil recovery at 1.2 PV-injected for each pressure setting is plotted (A sufficiently good match was attained).

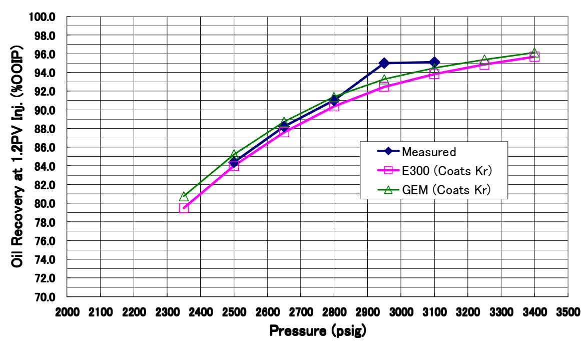

Figure 8 Comparison of Slim tube Test and EOS model simulation

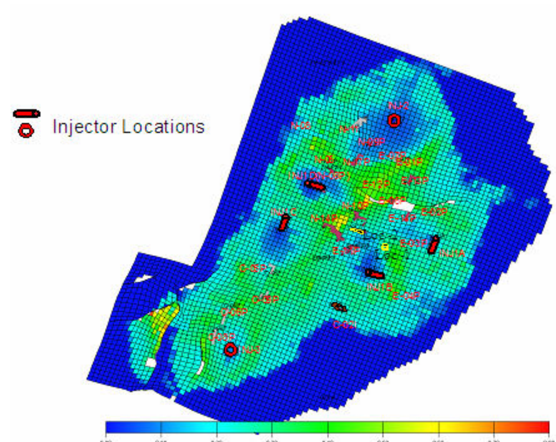

Figure 9 Simulation Model and Injector Location

The plane view of the grid system for the simulate ion model is shown in Figure 9. The model is composed of 97 x 116 x 40 (corresponding to divisions in the x, y, and z directions) grid blocks.

The well locations for the base case of CO2 injection are shown in Figure 9. Simulation settings are summarized as follows.

- The number of CO2 injectors: 6
- CO2 and Water Injection: 3-month CO2 injection, then 6-month water injection as 1 cycle
- CO2 injection period: total 7.5 years

Before CO2 injection, water injection is planned to raise the reservoir pressure for 3 years since a higher reservoir pressure promotes the development of miscibility or near miscibility with CO2. The field total CO2 injection rate is planned to be 52 MMSCF/D (about 2,700 ton/d) and all produced CO2 is to be recycled to minimize CO2 emission to the atmosphere.

The calculated oil production performance by CO2 injection case is shown in Figure 10, compared with that of waterflood case. Figure 11 shows the change of oil saturation distribution at a layer of the model in simulation. In this figure, it is clearly observed oil around CO2 injector is swept well by CO2 injection.

CO2 injection brought a field cumulative oil production equivalent to 42% of OOIP. CO2 injection project is summarized as follows.

- Total CO2 Injection : 7.5 million ton (8 years)
- Oil Recovery Increment against Waterflood : 8%

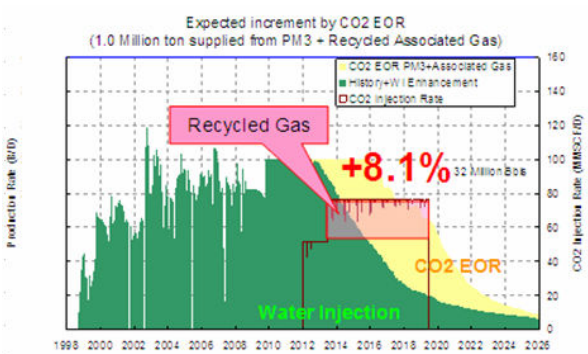

Figure10 Field oil production forecast by waterflood and CO2 WAG (Base Case)

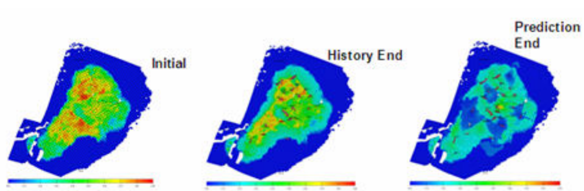

Figure 11 Change of oil saturation distribution in CO2 Injection Case

CO2 injection related cost and economics

In order to inject sufficient amount of CO2 into the reservoir in the offshore field, a site survey of CO2 sources was carried out by visiting cement plant, power plants and fertilizer plant. Separately from the industrial plants, a gas field with CO2 was also nominated as a CO2 source. As a result, some of the visited industrial plants seemed not suitable due to the distance (the cement plant is over 300 km away from the field), low concentration of CO2 (CO2 concentration of power plant is 3% only) and insufficient volume of CO2 availability. Finally, two CO2 sources were selected for the preliminary feasibility study. One is the gas field with separated CO2 emitted to the atmosphere, which is far from the field (over 500 km CO2 transportation pipeline is required) and the other is the fertilizer plant.

In order to receive/inject CO2 and to protect from corrosion by breakthrough CO2, new platform with CO2 compressor and CO2 treatment system is considered to be required nearby current facility. Produced CO2 rich associated gas is assumed to be recycled without CO2 capture process (re-injection and no CO2 emission). Their rough costs including CO2 Capture/Transportation, new platform and well drilling/workover are estimated in the order of 700 – 1,000 MMUS$.

Current Situation and Further Plan

Through this study, it is concluded the technical feasibility is very high, dependent on the field pilot test results, however, economical feasibility seems not so high due to the cost. All the joint study party including PVN is considering the importance of the field pilot test as well as economics improvement. As a next step, a field pilot test is planned in this field to evaluate the effectiveness in the real field application and the expansion of CO2 EOR application not only to this field but to the surrounding filed(s) to share CO2 injection/treatment cost each other.

APPLICABILITY STUDY ON JAPAN-GTL TECHNOLOGY TO OFFSHORE VIETNAM GAS FIELD

There are several gas field development methods to be selected, i.e. transportation of the gas to the onshore to be used as a city gas or power/chemical plants and LNG. Recent years, GTL (Gas to Liquid) technology has been studied and applied worldwide by several different methods. GTL is one of the emerging gas technologies, with which natural gas as a raw material can be converted into petroleum products. It is an extremely effective method to gain alternative fuel sources to petroleum and achieve the diversification of primary energy supplies.

Besides, GTL has a variety of advantages: e.g.; it is available to monetize stranded gas reserves and contribute flaring reduction for upstream business and it has environmental advantages such as sulfur/aromatic free and realizes efficient performance of diesel engines due to very high Cetane Number and furthermore enables to utilize the existing infrastructure and facilities for downstream business. It is known GTL is anticipated to increase the share of Global Liquid Production in the future as shown in Figure 12.

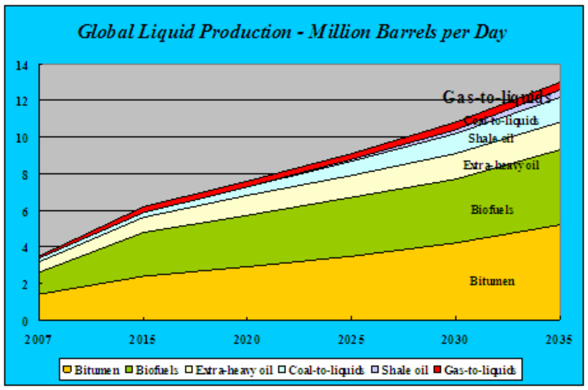

Figure12 Global Liquid Production (2007 – 2035) from International Energy Outlook 2010

JAPAN-GTL Technology

JOGMEC has been tackling the research and development of the natural gas conversion technology since 1998. JOGMEC made the "Joint Research Contract" with Nippon GTL Association established by six private firms in 2006, following the Yufutsu Pilot Test Project (2001 to 2004), in order to conduct the Demonstration Project (500BPD) scheduled 5 years with an eye toward potential international gas field development with the capacity of 15,000 to 20,000 BPD per train (refer to Figure 13).

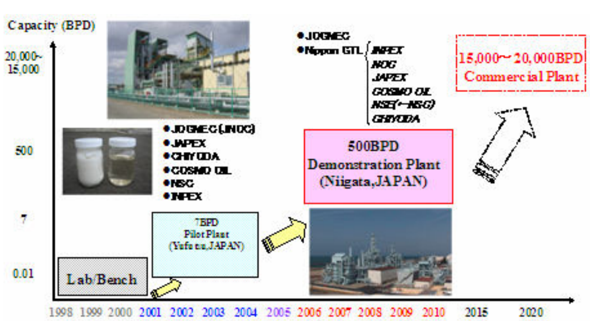

Figure 13 JAPAN-GTL History of R&D Activities

The construction of the JAPAN-GTL Demonstration Plant in Niigata (refer to as "Demonstration Plant") was completed in March 2009 and it has been in operation since 16th April 2009. The production of 500 barrels (about 80 kiloliters) per day was achieved.

The JAPAN-GTL process contains three core processes as shown in Figure 14: synthetic gas production section (refer to as "Syngas"), FT (Fischer-Tropsch) production section (refer to as "FT") and Upgrading (hydrocracking) section (refer to as "UG"), which equip with proper catalysts developed by Chiyoda, Nippon Steel Eng. and NOE (formerly known as NOC), respectively. They have been tested in the Demonstration Plant. Naphtha, Kerosene and Gas Oil are produced from natural gas including CO2.

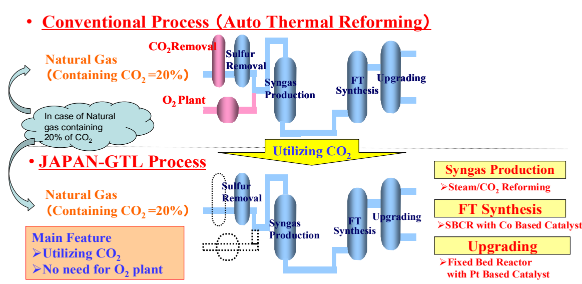

Figure 14 Characteristics of JAPAN-GTL Process

(a) Technical and Cost Advantages of JAPAN-GTL Process

Steam/CO2 reforming in the Syngas reformer is one of particularities of JAPAN-GTL process as appears in Figure 14, which illustrates main distinction between JAPAN-GTL process and conventional GTL processes. The Syngas Reformer efficiently uses CO2 included in the natural gas feedstock and it enables to produce Syngas, which consists of H2 and CO with the composition molar ratio of H2/CO=2/1. Thus, JAPAN-GTL process is capable to utilize CO2 contained in the natural gas directly and does not require any O2 supply. In summary, the characteristics of JAPAN-GTL process in contrast to those of the existing ones using ATR or POx are (1) no use of the O2 generator, (2) no use of the CO2 removal unit, and (3) no use of the H2 conditioning unit for Syngas. The Syngas will be introduced to the subsequent FT Reactor to convert it to GTL production oil.

GTL product is light oil and heavy oil. Figure 15 shows samples of produced at Yufutsu GTL pilot plant. The analyzed property of light oil shown in Table 1 demonstrated that they are super clean fuels, because of no sulfur and no aromatic contained.

Figure 15 Produced Heavy Oil (Left) and Light Oil (Right) by Yufutsu GTL Plant

Table 1 Property of Light Oil

Item		A	B
Density	15℃, g/cm^3	0.7566	0.7525
Kinematic Viscosity	30℃,mm^2/s	1.853	1.616
Distillation	10%, ℃	131.0	129.5
	50%, ℃	221.0	207.5
	90%, ℃	302.0	286.5
Aromatic	mass ppm	<1	<1
Sulfur	mass ppm	<10	<10

(b) JAPAN-GTL Advantage in terms of CO2 Emission

As for CO2 emission, JAPAN-GTL has more advantage than the existing GTL technologies.

Fig. 16 shows the comparison of CO2 emission by the different technologies.

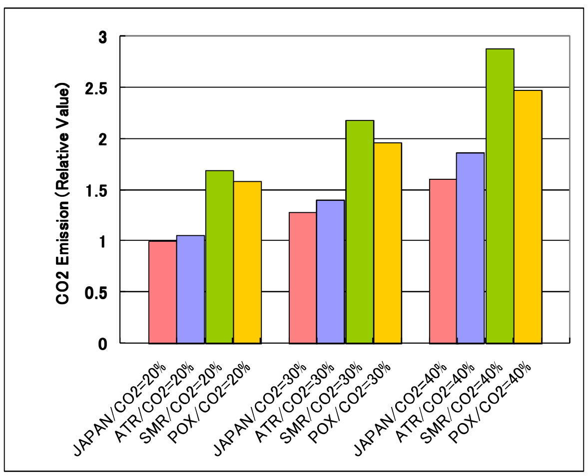

Figure 16 Comparison of CO2 emission

In this figure, the amount of CO2 emission expresses the relative values to the JAPAN-GTL for CO2 20% case. As clearly seen in this figure, JAPAN-GTL has the smallest CO2 emission compared with SMR, ATR, and POX in all the cases. Especially, more CO2 case has much less CO2 emission than the other methods.

Joint Study on the Applicability of JAPAN-GTL Process to Offshore Vietnam Gas Field

Preliminary Feasibility Study has been conducted from 2007 to 2009 among JOGMEC, PVN and VPI.

The aim of the study is to clarify the availability of JAPAN-GTL process to offshore gas fields in Vietnam. As specific offshore gas fields were not nominated in the study, JOGMEC assumed applying imaginary offshore gas field in Vietnam as the target gas field by the following assumptions.

- Distances from shore (50, 100 and 150km) and water depths (50, 100 and 200m)
- GTL Plant capacities (7,500, 15,000 and 30,000BPD)
- CO2 contents (0, 20 and 40%)

As a result, it was concluded JAPAN-GTL will be a candidates to apply to Vietnam offshore gas field. Further detailed feasibility study for a specified gas field is planned.

CONCLUSIONS

- JOGMEC and VPI have been jointly conducting studies on CO2 EOR and JAPAN-GTL technologies.
- The field pilot test of CO2 EOR is planned in southern Vietnam offshore oil field before field-wide application. CO2 EOR project is considered to be environmental-friendly technology by increase oil production as well as reducing CO2 emission, however, this project seems sub economical due to huge investment for CO2 separation/transportation and corrosion protection for the field.
- JAPAN-GTL technology is potentially an application technology for stranded CO2 contained offshore gas field in Vietnam. This technology seems to have environmental advantages by utilizing CO2 directly for GTL process up to 40mol%.
- JOGMEC and VPI are considering the emerging technologies of CO2 EOR and JAPAN-GTL to develop Vietnam offshore oil/gas fields as well as CO2 reduction technologies. The integration of the technologies can contribute to the effective utilization of CO2.

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