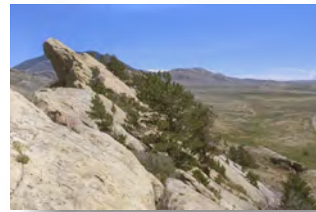
Chapter 23

Calculation of Estimated Ultimate Recovery (EUR) for Wells in Continuous-Type Oil and Gas Accumulations



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By Troy Cook

Chapter 23 of

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By USGS Southwestern Wyoming Province Assessment Team

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Abstract

The calculation of Estimated Ultimate Recovery (EUR) from oil and gas production data of individual wells and the development of EUR distributions from all producing wells in an assessment unit are important steps in the quantitative assessment of continuous-type hydrocarbon resources. The U.S. Geological Survey has developed a method of calculating EURs for wells in continuous-type accumulations, including coalbed gas accumulations. The EUR distribution of producing wells is used as a guide for the estimation of an EUR distribution for potential wells in areas of undiscovered resources.

Introduction

The U.S. Geological Survey (USGS) assesses two categories of hydrocarbon accumulations: conventional and continuous. A conventional oil or gas accumulation is characterized by a discrete field in which the hydrocarbons are buoyant upon a water column with a well-defined hydrocarbon-water contact (fig. 1). In the assessment of undiscovered conventional accumulations, the emphasis is placed upon the sizes and numbers of discovered accumulations as a guide to the sizes and numbers of undiscovered accumulations. In continuous-type hydrocarbon accumulations (also referred

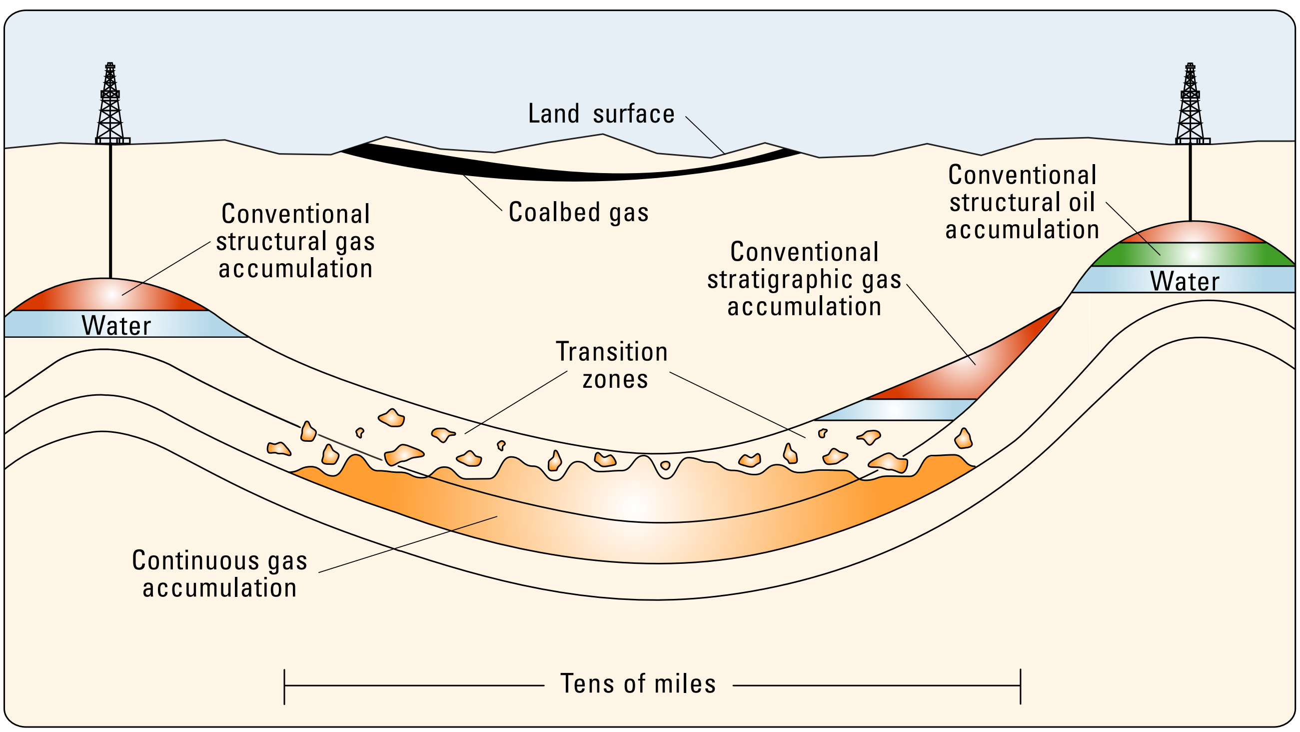

Figure 1. Categories of oil and natural gas occurrence as used in the National Assessment of Oil and Gas Project (Schenk and Pollastro, 2002).

to as unconventional, tight-gas, shale gas, low-permeability sandstones, and basin-centered accumulations), the hydrocarbons are distributed throughout a large area rather than being concentrated into a discrete field. These accumulations do not have well-defined hydrocarbon water contacts and commonly are abnormally pressured. Such hydrocarbon accumulations typically do not have any truly dry holes, although some wells may be abandoned due to poor production results. Continuous-type accumulations occur in many lithologies, but are most common in sandstones and fractured shale. Coalbed gas is a special type of continuous hydrocarbon accumulation.

Continuous-type accumulations require a different assessment methodology than the methodology used for conventional accumulations. The methodology for continuous accumulations uses the Estimated Ultimate Recovery (EUR) of cells, a cell being a geologically defined area that is drained by one or more wells in a continuous accumulation. The USGS approach is to calculate the EUR for all wells that have produced from an assessment unit. The EURs are grouped into EUR distributions, and the EUR distribution of produced wells is used as a guide for wells that have the potential to be drilled in the same assessment unit. The purpose of this chapter is to outline the process whereby an EUR is calculated for a well in a continuous accumulation, and to illustrate the graphical method for displaying the EUR distribution of an assessment unit.

Source of Oil and Gas Production Data

The primary source of domestic oil and gas production data is the IHS production database on CD–ROM (IHS Energy Group, 2001). Monthly oil and gas production data are stored on a lease-by-lease basis. Oil and gas production data are exported from the database into a software package that allows curves to be fit to the data. In areas where data are not available from this commercial database, oil and gas data are obtained from State sources. Considerable time and effort are required to form a single formatted production database from multiple State sources.

Screening Process for Production Data

For assessment purposes, a set of rules was developed to ensure that the production data from the commercial database led to EURs for single wells. Production data are commonly reported by leases rather than by single wells, so the decision was made to apportion the production reported within a lease equally to the number of wells in a lease. Thus, each well in a three-well lease would be given one-third of the total lease production as reported in the database. This process is not completely satisfactory, as it does not allow for differences in the initial production date for wells within a lease, nor are differences in production between wells taken into account. A more satisfactory process is to create an EUR from a single-well lease, but some assessment units contain a large percentage of multi-well leases. A well with no reported production for 2 years prior to an assessment is assumed to be incapable of further production, and the cumulative production to that time is considered to represent the EUR for the well.

Estimated Ultimate Recovery (EUR)

An EUR is an estimate of the expected ultimate recovery of oil or gas from a producing well. Several methods are used to estimate an EUR, and the methods differ depending upon the purpose of the study. For USGS assessment purposes, the production data for individual wells are analyzed for rate of production during some specified lifespan of a well. However, for a given assessment unit defined by a geologist, the production database commonly contains only a subset of the wells known to produce in the assessment unit. In general, for wells with oil or gas production data, the data are plotted with respect to time, and a hyperbolic or exponential decline curve is fit to the data. The intersection of the decline curve with the X-axis terminates the forecast span of the well, and the EUR is the sum of all oil or gas that is forecast to have the potential to be produced up to the termination point (fig. 2).

Using this procedure, an EUR is calculated for each well with production data in an assessment unit. An EUR distribution is constructed by ranking all of the calculated EURs from smallest to largest. The ranked EURs are plotted on semilog paper with the EURs on the Y-axis and the percentage of wells in the subset of producing wells on the X-axis (fig. 3).

EUR Methodology for Producing Wells in Continuous-Type Accumulations

A methodology was developed for the calculation of an EUR for a well in a continuous-type accumulation, exclusive of coalbed-gas accumulations. First, wells which had not produced in the 2 years prior to the assessment were considered shut in, and the EURs for these wells were assumed to be the cumulative production. If only a few months of production data were available, the well was excluded from the dataset because a representative curve could not be drawn. Next, the production data for each well were fit with a hyperbolic or exponential curve. The curve was fit to the entire string of production data rather than to just the declining portion of the data as is commonly done in many engineering applications. Once the shape of the curve was determined by the curve-fitting procedure, a process was developed to vary the lifespan of a well. A Monte Carlo simulation was used to vary the lifespan of a well, with a small change, both positive and nega-

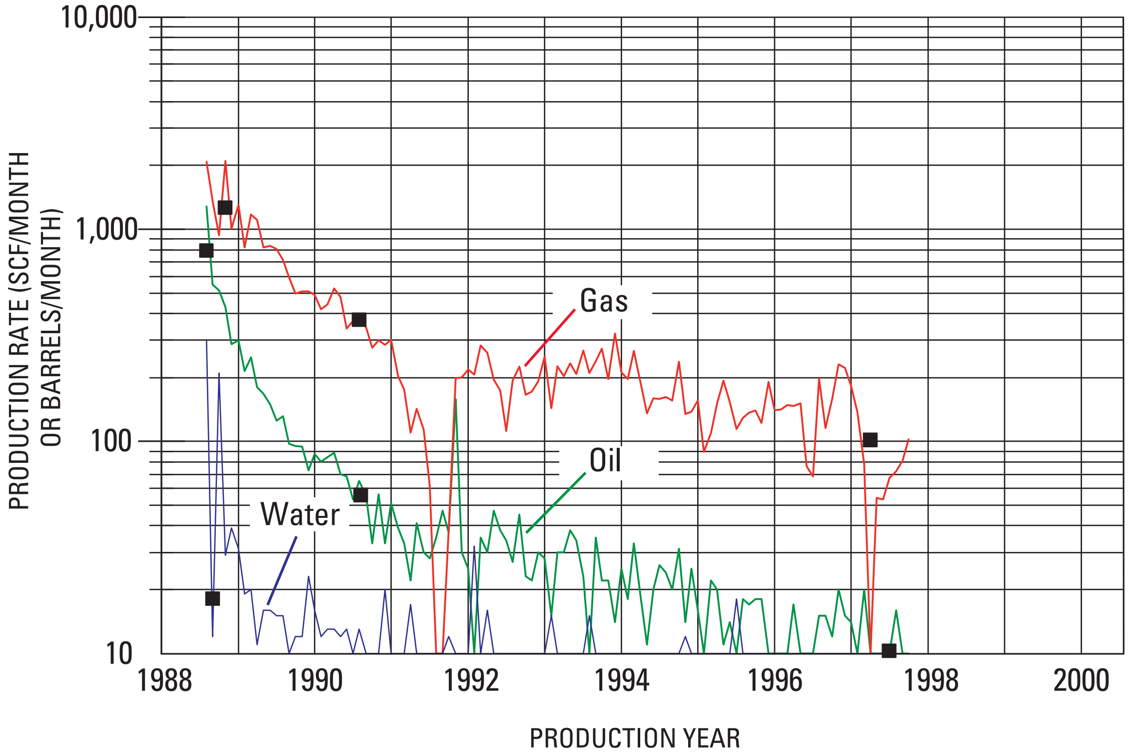

Figure 2. Oil, gas, and water production data from a well in a continuous-type accumulation. Rate of gas production (thousand standard cubic feet (SCF)/month) shown in red; rate of oil production (barrels/month) shown in green; and rate of water production (barrels/month) shown in purple.

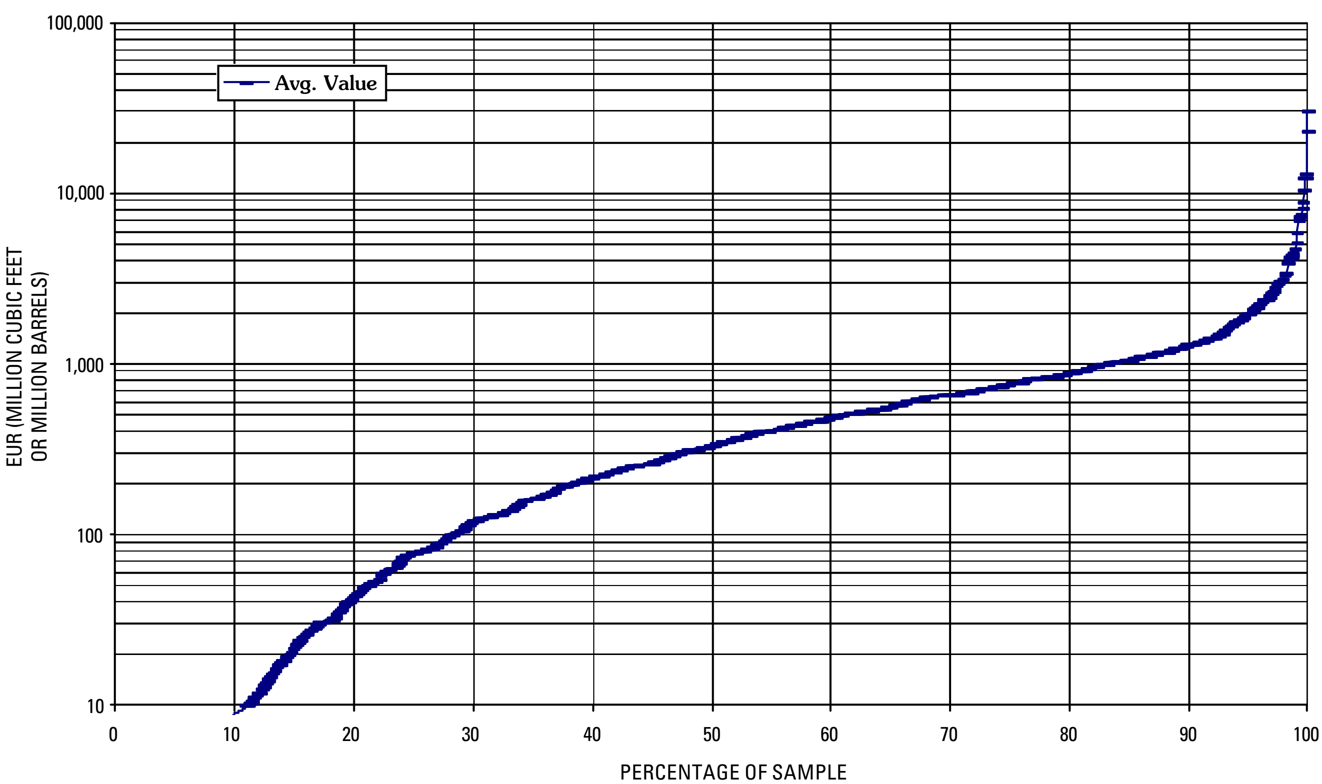

Figure 3. Example of an EUR distribution for a continuous-type accumulation. A value of 50 percent on the X-axis means that 50 percent of the EURs in the data set were less than that value, and 50 percent were greater than that value on the Y-axis.

tive, being used to alter the shape of the decline curve. The simulation was run several thousand times for each well. The mean result from the simulation was the EUR for the well. For each well, fractiles of probability at the F_5, F_{25}, F_{50}, F_{75}, F_{95} and the mean were retained from the simulation.

The Monte Carlo simulator was programmed to recognize time as the only limit to lifespan of a well. This aspect of the analysis differs from engineering-type EUR calculations that incorporate economic factors such as well operating costs and product prices. After calculation of the EUR, a final screening process took place. If the cumulative production of a well was less than 2 percent of the forecast EUR, the EUR was dropped from the dataset. This screening prevented the inclusion of EURs that were extrapolated from a limited production data string. The remaining EURs were then assembled into a ranked plot (fig. 3).

To gain an understanding of how EURs may change with time in an assessment unit, the EUR distribution was divided into thirds based on the initial date of production of each well. The EUR distribution was then replotted as three curves, each representing one-third of the distribution. In this way the assessor could observe any changes in EUR through time in the assessment unit (fig. 4). The EUR “thirds” plot commonly shows that the median EUR decreases with time as more wells are drilled.

EUR Methodology for Producing Wells in Coalbed Gas Accumulations

Coalbed gas wells require a slightly different approach in the calculation of EUR because of the necessity of removing water from a coal bed before natural gas becomes mobile. As water is removed from a coal, the amount of produced gas increases. Thus, the production curve for most coalbed gas wells exhibits an initial increase in production compared to wells in other types of continuous accumulations. The length of time for the increase in production may be several years.

The unique shape of the production profile for coalbed gas wells was divided into three production phases as a first step in the calculation of an EUR (fig. 5). The first phase of the production curve is the initial increase in production as a coalbed is dewatered. The second production phase is the roll-over point, during which the production peaks and begins to decline. The third phase is the production decline, the tail of which is extrapolated beyond the data using an exponential decline function similar to the decline functions applied to other types of continuous gas wells.

The following procedure was used in the calculation of an EUR for a typical coalbed gas well. The production data of each well were examined to determine the current production phase of the well. Each section of the production curve was then quantified and the resulting data were input into four tables internal to the program. Table 1 contains the Initial Production (IP) point. Table 2 contains the rate of production increase during the first phase of production. The roll-over point of production is listed in table 3. The rate of decline during the third production phase is contained in table 4. These four tables were then used to simulate the production life of a hypothetical coalbed gas well using a Monte Carlo simulator. The data from these coalbed gas wells were then used to fill in missing portions of a production stream in another coalbed gas well. For example, if data from a well included the first and second phases, the model would be used to construct an analog for the missing part of the coalbed production profile for the well.

During the analysis of each coalbed-gas production curve, several fractiles of probability were extracted from the curve and saved for future reference by the Monte Carlo simulator. The fractiles included the F_5, F_{25}, F_{50}, F_{75}, F_{95}, and the mean. These fractiles for each well were further used in the calculation of the EUR distribution.

Summary

The calculation of EUR and the development of the EUR distribution for an assessment unit represent the cornerstone for the methodology used by the USGS to assess continuous-type resources. The EUR distribution is used as a guide to the EUR distribution of potential cells in the undiscovered portions of continuous assessment units.

References Cited

IHS Energy Group, 2001, [includes data current as of December, 2000] PI/Dwights Plus U.S. Production and Well Data: Englewood, Colo., database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A.

Schenk, C.J., and Pollastro, R.M., 2002, Natural gas production in the United States: U.S. Geological Survey Fact Sheet FS–113–01.

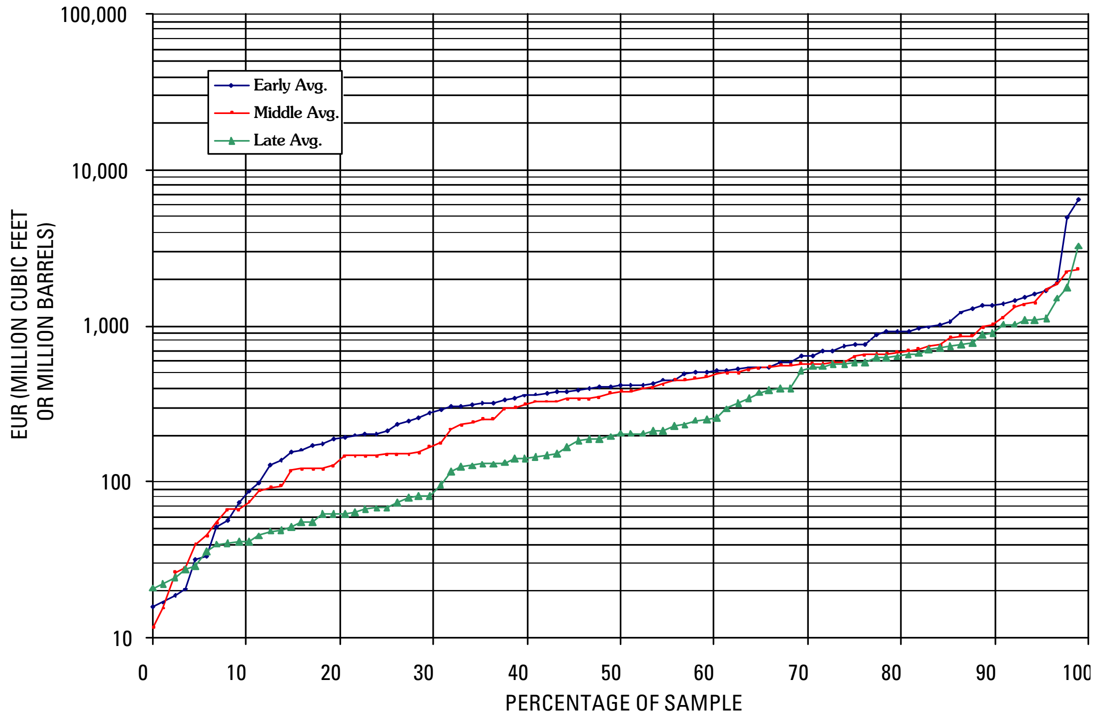

Figure 4. Example of an EUR distribution divided into thirds to illustrate changes in EUR through time for a continuous-type accumulation. The curves show that the median EUR decreases with time, a characteristic of maturely explored continuous-type assessment units. A value of 50 percent on the X-axis means that 50 percent of the EURs were less than that value, and 50 percent were greater than that value on the Y-axis. Commonly, the largest EUR decreases with time (wells with larger EURs are discovered early).

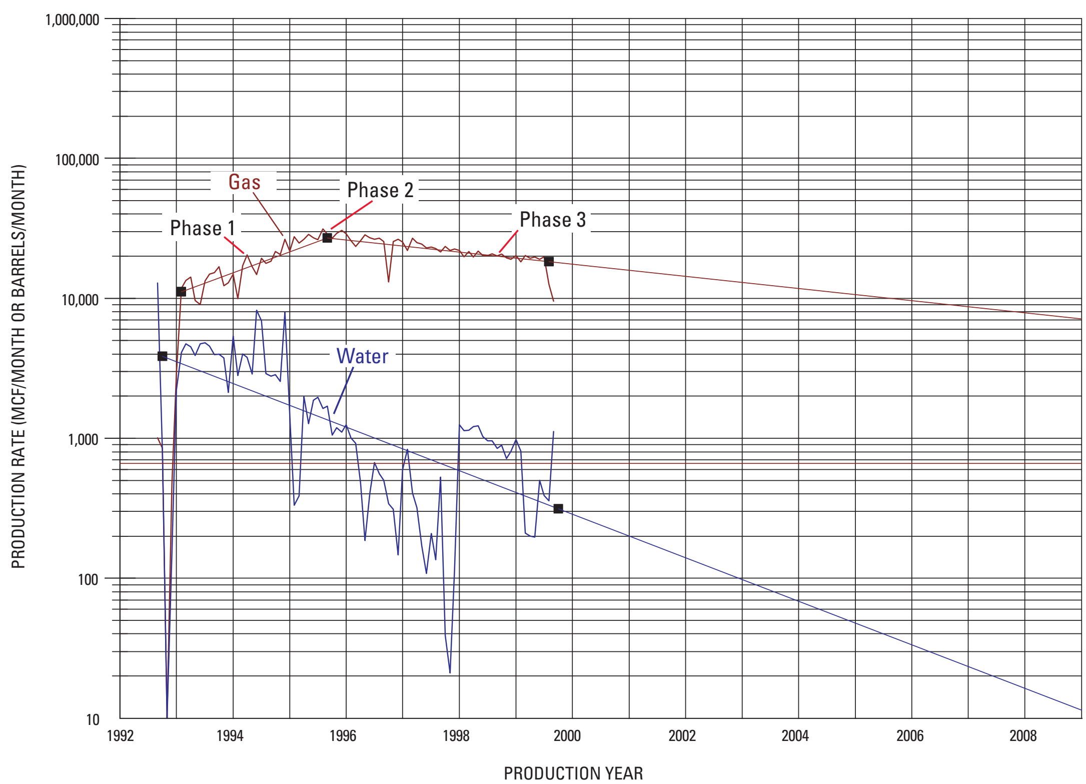

Figure 5. Typical production histories and curves for gas and water production from a coalbed gas well. Rate of gas production (thousand cubic feet (MCF)/month) shown in red, and rate of water production (barrels/month) shown in blue. Note that gas and water curves have forecast "tails" that extend beyond the last record of production. For analysis of a well EUR, production data for a coalbed gas well are divided into three phases.

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