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THE WORKBACK METHOD AND THE VALUE OF HELIUM*

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ABSTRACT

It is sometimes the case that the value of a resource at one stage of production must be assessed in the absence of a well defined market at that stage. One tool for valuation is the "workback" method, which imputes a value to a resource at an early processing stage by subtracting from an observed price for the resource at a more refined stage all of the costs incurred between the two stages. The workback method has been used by the courts in attempting to assess the wellhead value of helium extracted from helium-bearing natural gas streams during the Helium Conservation Program. This paper describes conditions necessary for a correct application of the workback method generally, and then provides an economic analysis of two court decisions using the workback method in the helium industry. Most importantly, the paper shows why a correct application of the workback method requires an understanding of market structure, whether the method is applied to helium, other natural resources, or more general multistage production processes.

I. INTRODUCTION

During the period of 1962-1973, the federal government purchased and stored large amounts of helium under a helium conservation program. The value of the helium produced at the wellhead has been the focus of a number of recent court cases. The issue of valuation would have been straightforward if the courts had agreed that helium produced at the wellhead had been sold into a competitive market, in which case the market price would represent the value of helium. In 1974 a district court in Kansas decided that there was sufficient competition at the wellhead to use the market price, and that the value was approximately $0.60 to $0.70 per Mcf (thousand standard cubic feet).[1]

However, a similar case tried in the Northern District Court of Oklahoma in 1973 led to a markedly different conclusion. The court concluded that the various sales of helium at the wellhead were sufficiently different in time and place so that no single contract price could be used to represent the value of helium.[2] The court then calculated the value of helium using the "workback method," which imputed a value to helium at the wellhead by subtracting from an observed price for helium at a processed stage all of the costs incurred during processing. There were two major points that had to be resolved by the court: (1) which market for processed helium should serve as a starting point for the workback method, and (2) what costs of processing should be subtracted to obtain a "proper" value at the wellhead. The particular

application of the workback method chosen by the court led to a wellhead value calculated to be somewhere between $11 and $17 per Mcf.

Both cases were appealed to the Court of Appeals for the Tenth Circuit, which consolidated the two cases. By 1977 the appeals court had taken no action on the decision of the Kansas district court. In May 1977 it affirmed the decision of the Oklahoma court with respect to the use of the workback method, but remanded the case for further consideration of the proper starting value from which workback calculations would be made, the costs of processing, and more generally, other issues pertinent to the use of the workback method.[3] Thus, in August 1978, the case was heard again in the same Oklahoma district court that had issued the ruling in 1973 that helium at the wellhead was worth between $11 and $17 per Mcf.

The author appeared as an expert witness for the government in that trial, for the purpose of showing how the workback method should be used in the valuation of helium. In part this paper is based on the author's testimony in that case. Specifically, this paper shows why an application of the workback method must be undertaken with an understanding of basic economic principles, particularly with respect to the choice of an appropriate starting point. We show how the Oklahoma district court incorrectly applied the workback method in 1973, and then changed its application in 1978 to eliminate a fundamental economic error in its earlier ruling.

Although this paper specifically deals with helium, it is important to note that the general issues of valuation arise in connection with many natural resources. The principles enumerated in this analysis demonstrate certain conditions necessary for an appropriate application of the workback methodology. This is especially important where there are a number of processing stages that might serve as potential starting points.

II. HELIUM AS A NATURAL RESOURCE

Helium has several chemical and physical properties that make it important in certain scientific and industrial uses. It is light, inert, and liquifies at a very low temperature relative to most other elements. It is therefore useful in creating controlled atmospheres, for breathing mixtures, in welding, and in purging and pressurizing (e.g., in space technology). It also is useful in cryogenics, primarily as a medium for preparing supercooled networks which have very low resistance to the flow of electric current. In that capacity helium may greatly facilitate the operation of large scale power generation systems. Helium also has many other uses, including nuclear power, detection of leaks (because of its small molecular diameter), and lifting.

Helium is abundant in air, but only in concentrations of about five parts per million. It is possible to extract helium from the air at a cost of about $2500 per Mcf using existing technology.[4]

However, helium is also available in much higher concentrations from many natural gas fields. Much of it occurs in natural gas streams which are "rich" in helium (i.e., helium constitutes more than 0.3 percent of the stream). Other large amounts of helium are found in less concentrated "lean" natural gas streams.[5]

The rapid depletion of natural gas reserves has posed an interesting problem in the management of helium resources over the last two decades. As a natural gas stream is recovered, transported, and consumed, any helium associated with that stream will be passed into the air at the burner tip if it is not extracted earlier. It is much more expensive to recover helium from the air than from a helium rich natural gas stream. (Using existing technology, it may take as much as eight hundred times as much energy to extract helium from the air as from a natural gas stream.)[6]

Before 1960 the government extracted enough helium from natural gas streams for its own current use. However, no program for storing helium existed. By 1960 a number of new uses for helium led to a growing concern that the Bureau of Mines would not be able to produce enough helium from its own plants to meet the demand for helium after 1985.

The Helium Conservation Program

These concerns led to the passage of the Helium Act of 1960,[7] which established a helium conservation program. Under this program the Bureau of Mines entered into contracts to purchase

helium from four private companies, called Helex companies.[8] The Helex companies were to extract helium from natural gas streams, and to sell the extracted helium mixture to the Bureau of Mines. The extracted helium mixture was termed "crude helium," whose helium content was approximately fifty to seventy mole percent (see Table 1).

The Bureau of Mines combined the crude helium it purchased with some of the helium it produced from its own plants, and injected the helium into a partially depleted natural gas field (the Cliffside field) near Amarillo, Texas. The Bureau planned to store enough helium so that, counting its own gas fields, over 40 billion cubic feet of "contained" helium would be available for future use. Contained helium refers to the amount of grade A helium (99.995 mole percent helium) that could in principle be extracted from the crude helium mixture. The stored helium was intended to meet the essential government needs for helium after 1985. As Table 1 shows, all of the Helex company plants were operating by 1963.

By 1967 it was apparent that the actual demands for helium were falling well short of the amounts projected at the time the helium conservation program was established, and it was also apparent that this trend would continue. In addition, expectations developed for the discovery of substantial quantities of new reserves of helium. These were among the reasons cited by the Secretary of the Interior for terminating the helium purchase contracts in 1973.[9] Thus, after 1973 the government ceased buying helium from the Helex

TABLE 1

Helium Plants in the United States

Plant	Location	Initial Operation	Final Operation	Approximate Average Helium Content of Gas, Mole Percent	Nominal Capacity Helium MMcf/Yr	Nominal Product Purity (Mole Percent)
Bureau of Mines:						
Amarillo	Amarillo, Tex.	April 1929	April 1970*	1.8	80	99.995 gas
Exell	Masterson, Tex.	March 1943	July 1972*	.9	360	99.995 gas
Otis	Otis, Kans.	October 1943	April 1968*	1.4	50	99.995 gas
Navajo	Shiprock, N. Mex.	March 1944	July 1968*	5.7	80	99.995 gas
Keyes	Keyes, Okla.	August 1959		2.0	420	99.995 gas
Private Industry:						
Kerr-McGee, Inc.	Navajo, Ariz.	November 1961	February 28, 1976*	8.4*	75	99.995 gas
Kansas Refined Helium	Otis, Kans.	April 1966		1.3*	180	99.995 gas and liquid
Alamo Chemical Co.	Elkhart, Kans.	December 1966		.59*	140	99.995 gas and liquid
Cities Service Cryogenics	Scott City, Kans.	October 1968		.50*	200	99.995 gas and liquid
Arizona Helium 1/	Navajo, Ariz.	October 1968	December 1973*	8.4*	25	99.995 gas
Air Reduction	Teec Nos Pos, Ariz.	May 1968	September 1969*	6.0*	25	99.995 gas
Navajo Tribe 2/	Shiprock, N. Mex.	October 1968	September 1969*	6.1*	90	99.995 gas
*Linde Div. Union Carbide	Amarillo, Tex.	September 1967	October 1968*	3/	Unknown	99.995 gas and liquid
Western Helium Corp.	Shiprock, N. Mexico	February 1975		5.0	50	99.995 gas
*Linde Div. Union Carbide	Bushton, Kans.	November 1977		4/*	75*	99.995 gas
Former Conservation:						
Northern Helex, Inc.	Bushton, Kans.	December 1962	5/	.46	675	60.0 gas
Phillips Petroleum Co.	Hansford Co., Tex.	December 1962	5/	.78	360*	50.0 gas
Phillips Petroleum Co.	Dumas, Tex.	April 1963	June 1976	.65	428*	50.0 gas
Cities Service Helex, Inc.	Ulysses, Kans.	June 1963	6/	.43	610	60.0 gas
National Helium Corp.	Liberal, Kans.	July 1963	November 1973*	.40	1,052	60.0 gas

Sources of data: Bureau of Mines, Mineral Facts and Problems, 1965 and 1970 editions, except that items or lines marked with * are based on Bureau of Mines records.

1/ Later known as Western Helium Corporation. Plant has operated intermittently. Closed from October 1969 through October 1970; June 1971 through December 1971; and plant shut down in December 1973.
2/ Formerly Bureau of Mines Navajo Plant--transferred to Navajo Tribe of Indians via Bureau of Indian Affairs.
3/ Helium-gas mixtures produced at other plants.
4/ Plant gas supply is the crude product of the Northern Helex, Inc., plant.
5/ Output being stored or sold to others.
6/ Output being vented and/or stored or sold to others.

Source: Ashland Oil Company vs. Phillips Petroleum Co. CIV No. 67-C-238 (1978) United States Exhibit ____.

companies. Consequently, some Helex plants have been shut down, and the helium produced by the others was vented to the air, sold to private buyers, or, since 1975, stored by private producers at Cliffside under a storage program initiated by the Bureau of Mines.

A number of complex lawsuits have resulted from the helium conservation program. These lawsuits can be placed in two broad categories. The first type stems from the termination of the helium conservation program in 1973, in some cases twelve years before the government purchase contracts were originally scheduled to expire. This paper does not address those legal actions involving alleged breach of contract.

The second class of actions (the one of concern here) focuses on the value of helium at the wellhead. Although some helium-bearing natural gas was purchased for its helium content before 1960 helium was generally considered of little value. Sellers of helium-bearing natural gas did not usually seek additional compensation for the helium. In some cases helium was sold to helium extraction plants at $2 to $3 per Mcf, including transportation costs. [10]

Each Helex contract specified the price at which the government would purchase the crude helium mixture from the Helex companies. The crude helium prices were on average about $11 per Mcf at the beginning of the program (see Table 3, discussed in detail below). To produce crude helium, the Helex companies purchased helium from helium-bearing natural gas streams. Under the Helex contracts, the Helex companies were to incur the purchase

costs of the helium they acquired up to a wellhead price of about $3 per Mcf. The government agreed to bear any additional amounts that the Helex companies might have to pay for helium purchased at the wellhead from nonaffiliated producers as long as the payments were with the "consent" of the government. Consent was defined to include third party claims judicially determined in favor of any claimant. Thus, both the government and the Helex companies have resisted the attempts of landowners and producers of helium-bearing natural gas streams to receive additional compensation for helium at the wellhead.[11]

If the Oklahoma district court had decided that the markets for helium at the wellhead and at the inlets to the Helex plants were sufficiently competitive to use the transactions prices as a value for helium, then no workback calculations would have been necessary. Since it ruled otherwise, it found it necessary to employ the workback method.

With this as background, we now describe the two markets for processed helium that the court examined as potential starting points for the workback method. These are the markets for crude helium and grade A helium. As we will show below, an understanding of the structure of these markets is essential to an economically sensible application of a workback method.

III. THE MARKET FOR CRUDE HELIUM

Data summarizing the production of crude helium in the United States from 1960 to 1975 are shown in Table 2. Prior to 1960,

the Bureau of Mines produced all of the crude helium in this country, at the plants listed in Table 1. By 1963 all of the Helex company plants had begun production. From 1964 until 1973, when the conservation program was terminated, the Bureau of Mines produced no more than 20 percent of the crude helium in any year. During the same interval the Helex company plants yielded between 80 and 85 percent of the total annual crude helium production. As Table 2 shows, between 1966 and 1973 a small percentage of the crude helium was produced by private companies other than the Helex companies.[12]

By 1964 the conservation program was in full swing, and it continued that way until 1971, when the federal government made its first efforts toward terminating the program. From 1964 to 1970 Northern was the smallest producer, with an annual production of between 15.3 and 18.1 percent of the total Helex company output. The largest producer among the helex companies was National, whose share of the total Helex company production annually was between 33.3 and 37.1 percent.[13]

Table 3 summarizes the purchases of crude helium from 1960 to 1975. During the years of the conservation program, the Bureau of Mines purchased over 90 percent of the crude helium sold. The average price paid by the Bureau of Mines for crude helium sold by the Helex companies is shown in column four.[14] The price received by any Helex company did not depart by more than $1.70 per Mcf from the price received by any other Helex company during the 1964 to 1970 period. Similar data for purchases of crude helium by private companies are also summarized in Table 3.

TABLE 2

Crude Helium or Equivalent Production

1960-1975

Calendar Year	Bureau of Mines		Private Parties				
	Mcf[1]	% of Total	Helex Cos, Mcf	% of Total	Other Mcf	% of Total	Total Mcf
1960	642,000	100.0	0	0	0	0	642,000
1961	727,100	100.0	0	0	0	0	727,100
1962	680,867	99.7	2,364	0.3	0	0	683,231
1963	774,200	35.6	1,398,295	64.4	0	0	2,172,495
1964	784,500	20.0	3,139,899	80.0	0	0	3,924,399
1965	691,700	16.5	3,494,377	83.5	0	0	4,186,077
1966	812,400	18.5	3,560,892	81.2	14,308	0.3	4,387,600
1967	714,800	16.5	3,605,603	83.2	11,869	0.3	4,332,272
1968	677,700	15.4	3,711,789	84.3	14,319	0.3	4,403,808
1969	666,900	15.3	3,646,686	83.6	48,559	1.1	4,362,145
1970	660,100	15.8	3,464,028	82.6	67,476	1.6	4,191,604
1971	678,032	18.0	3,021,062	80.1	70,963	1.9	3,770,057
1972	438,665	13.5	2,745,146	84.3	71,321	2.2	3,255,132
1973	356,090	12.8	2,352,893	84.7	69,802	2.5	2,778,785
1974	338,076	62.6	130,396	24.2	71,300	13.2	539,772
1975	368,249	53.5	256,071	37.2	64,095	9.3	688,415

1) Grade "A" (Gaseous) Helium produced directly from helium bearing natural gas representing an equivalent or more amount of crude helium, and crude helium produced after June, 1965.

Source: Ashland Oil, Inc. v. Phillips Petroleum and U.S., Northern District of Oklahoma, No. 67-C-238 (1978), Phillips Exhibit 42

TABLE 3

Crude Helium Purchases

1960-1975

Calendar Year	Bureau of Mines			Private Purchases			
	Mcf	% of Total	Wtd. Ave. Price $/Mcf	Mcf	% of Total	Wtd. Ave. Price $/Mcf	Total Mcf
1960	0	--	--	0	--	--	0
1961	0	--	--	0	--	--	0
1962	2,364	100.0	10.99	0	0	--	2,364
1963	1,398,295	100.0	11.65	0	0	--	1,398,295
1964	3,139,899	100.0	11.26	0	0	--	3,139,899
1965	3,494,377	100.0	11.32	0	0	--	3,494,377
1966	3,560,892	99.6	11.44	14,308	0.4	7.51	3,575,200
1967	3,562,387	98.5	11.64	55,085	1.5	11.55	3,617,472
1968	3,583,283	96.2	11.83	142,825	3.8	12.70	3,726,108
1969	3,588,618	97.1	12.07	106,627	2.9	14.45	3,695,245
1970	3,431,382	97.2	12.41	100,122	2.8	16.05	3,531,504
1971	2,964,250	95.9	12.84	127,775	4.1	14.81	3,092,025
1972	2,687,148	95.4	13.26	129,319	4.6	11.50	2,816,467
1973	2,257,611	93.2	13.62	165,084	6.8	10.47	2,422,695
1974	0	--	--	201,696	100.0	11.01	201,696
1975	0	--	--	320,166	100.0	10.25	320,166

Source: Ashland Oil, Inc. v. Phillips Petroleum and U.S., Northern District of Oklahoma, No. 67-C-238 (1978) Phillips Exhibit 43

IV. THE GRADE A HELIUM MARKET

Prior to the start of the conservation program, the federal government sold grade A helium to both government agencies and private purchasers, in amounts indicated in Table 4. Although the table does not show the weighted average price for those transactions, most of those transactions occurred at a price of approximately $19 per Mcf.[15]

When the conservation program began, by federal statute the government charged a price for grade A helium which would cover the cost of purchasing crude helium, storing it, and converting it to grade A helium. It therefore established a price of $35 per Mcf for all grade A helium purchased from the Bureau of Mines. Government departments and agencies were required to purchase from the Bureau of Mines, even if lower costs supplies of helium were available from private sources.

During the helium conservation program some private parties also sold grade A helium. Between 1962 and 1965, the only major private supplier was Kerr-McGee, which also set a price of $35 per Mcf.

Beginning in 1966, other major private suppliers entered. Kansas Refined Helium undercut the Kerr-McGee price by a very large amount. While Kerr-McGee was still charging $35 per Mcf in 1966, Kansas Refined Helium sold grade A helium at a weighted average price of $16.37 per Mcf. Thus the weighted average price for both suppliers was $25.39 during 1966, as shown in Table 4. From 1968 until 1972 there were four major suppliers of grade A helium, and

TABLE 4

Purchases of Grade A (gaseous) Helium
f.o.b. Plants, 1960-1972

Calendar Year	Purchased from Bureau of Mines					Purchased from Private Parties			Total Mcf
	Govt. Depts. and Agencies		Private Purchasers		Wtd. Ave. Price $/Mcf			Wtd. Ave. Price $/Mcf[2]	
	Mcf	% of Total	Mcf	% of Total		Mcf[1]	% of Total[1]		
1960	360,063	75.8	115,116	24.2	N.A.	--	--	--	475,179
1961	415,214	75.2	136,570	24.8	N.A.	--	--	--	551,784
1962	467,444	74.3	132,075	21.0	35.00	30,000	4.7	35.00	629,519
1963	473,700	71.2	153,600	23.1	35.00	38,000	5.7	35.00	665,300
1964	499,400	70.0	168,000	23.6	35.00	46,000	6.4	35.00	713,400
1965	479,400	63.3	219,500	29.0	35.00	58,000	7.7	35.00	756,600
1966	506,900	53.9	301,700	32.1	35.00	131,120	14.0	25.39	939,720
1967	418,600	52.1	188,400	23.5	35.00	196,084	24.4	21.94	803,084
1968	400,400	54.9	78,000	10.7	35.00	251,535	34.4	21.92	729,935
1969	284,000	43.1	76,700	11.6	35.00	299,118	45.3	20.46	659,818
1970	177,500	34.5	7,000	1.4	35.00	329,284	64.1	21.15	513,784
1971	138,563	32.0	6,000	1.4	35.00	288,003	66.6	21.00	432,566
1972	121,135	24.3	6,000	1.2	35.00	372,115	74.5	20.21	499,250

N.A. means not available

1) Includes the standard gaseous equivalent volume (Mcf) of balk liquid helium sales

2) Liquid helium sales are evaluated at grade "A" (gaseous) helium prices

Source: Ashland Oil, Inc. v. Phillips Petroleum and U.S., Northern District of Oklahoma, No. 67-C-238, Exhibit 48 (1978).

the increased rivalry resulting from entry led to a decrease in the price of grade A helium to approximately $20 per Mcf. After 1969 the prices charged by all of the producers were within about three dollars of one another. In particular, Kerr-McGee sold grade A helium at an average price of approximately $19.00 to $19.50 from 1970 to 1972.[16]

V. APPLICATION OF THE WORKBACK METHOD

In 1973 the Oklahoma district court selected the market for grade A helium as the starting point for the workback method, and used a price of $20 per Mcf as the price at that starting point. In "working back" toward the wellhead, it first subtracted the costs of refining crude helium to obtain grade A helium; these costs were determined to be $2 per Mcf. Thus the value imputed to crude helium was $18 per Mcf of contained helium.

The next stage in the workback method was to subtract from the value imputed to crude helium the costs incurred in extracting the crude helium mixture from the stream of natural gas. These cost determinations were quite complex, particularly since in the process of extracting crude helium, it was possible to obtain additional amounts of liquid hydrocarbons. There was a substantial debate as to whether the value of these "incremental liquids" should be viewed as a reduction in the extraction costs assigned to helium. The court in 1973 followed this practice, and subtracted from the total helium plant costs the value of the additional hydrocarbons

to obtain a net extraction cost for helium. Although the net cost for extracting helium varied from year to year, we note that on average the court determined this cost to be about $4 per Mcf for extraction.[17] Thus the workback method yields a value of helium at the inlet to the Helex plant of approximately $14 per Mcf.

Several particularly peculiar implications of the court's decision should be noted. The government had already paid, on average, about $12 per Mcf for crude helium (see Table 3). With the court decision, the government might have been liable for an additional $11 per Mcf for that same helium, since the Helex contracts would have made the government pay for all but $3 of the additional $14 per Mcf. Thus, the total payment of the government for crude helium would have been $23 per Mcf, more than the price paid for grade A helium.

It is also interesting to note that, had the court started with the price of crude helium and worked back, then the value at the wellhead would have been about $8 per Mcf ($12 minus the $4 average extraction cost). This is substantially less than the $14 per Mcf resulting when the $20 price of grade A helium is used as a starting point. The importance of this difference is emphasized further since literally billions of cubic feet of helium are in question.[18]

Even a wellhead price of $8 per Mcf might seem excessive in light of the earlier described sales at $2 per Mcf prior to the start of the conservation program. In fact, if the wellhead value of helium were actually $2 per Mcf, then producers and landowners

would be receiving a $6 per Mcf excess profit. In addition, if the Helex processing costs were $4 per Mcf, and if the government were ordered to pay the Helex companies for all helium purchase costs in excess of $3 per Mcf, then the Helex companies would also be realizing $5 per Mcf in excess profits ($12 - $4 - $3) on average.

The 1978 Case

In 1978 the Oklahoma district court retried the case on remand.[19] It found that the appropriate starting point was the crude helium market instead of the grade A helium market, and used as a starting point the $10.30 per Mcf price specified in the Phillips contract (since the case involved Phillips specifically).[20] It also increased its assessment of Phillips' processing costs to, on average, about $7.30 per Mcf, recognizing that it had understated the fair rate of return in its earlier ruling, and making other adjustments to its cost calculations. Thus, the court ruled that a fair wellhead value of helium, obtained by the workback method, was about $3 per Mcf,[21] instead of approximately $14 per Mcf as it had earlier found, and instead of $11.70 per Mcf that it would have calculated had it started with $20 per Mcf in the grade A helium market and subtracted $2 per Mcf in refining costs and the revised $7.30 in Helex processing costs.

In this section we show that, given the choice between the crude and grade A helium markets as a starting point, the crude helium market is preferable on economic grounds. (This was the major thrust in the author's testimony in the 1978 retrial.)

At first examination, one might be tempted to assert that the discrepancy in the two workback method values ($3 compared with $11.70 per Mcf) arises because the helium markets are not perfectly competitive. It is true that a market with only four major sellers (as is the case in both the grade A and crude markets) is not typically characterized as perfectly competitive.

Yet the issue of perfect or imperfect competition is not the central one in analyzing the court's decision. Rather, the central point is this: Even if all markets were perfectly competitive, an important source of error is introduced if one uses the grade A helium market price as the starting point in a workback method designed to determine the value of helium at the wellhead.

To show this we observe (from the last columns of Tables 2 and 4) that the volume of helium contained in the crude helium mixtures ranged from more than three times the volume of grade A helium in 1963 to more than eight times the volume of grade A helium produced in 1970 and 1971. Thus the volume of grade A helium is much less than the volume of helium processed at the Helex plants during every year of the conservation program.

The error which arises is a clear example of a logical fallacy. It can be illustrated as follows. If we start with a $20 per Mcf figure for grade A helium, and subtract the $2 per Mcf cost of refining crude helium to grade A, then we impute a value of $18 per Mcf to all of the crude helium, based on the relatively small volume of grade A helium. This is logically equivalent to an

assumption that the much larger volume of crude helium could all be refined and sold as grade A at the price of $20 per Mcf. But that violates the economic Law of Demand, which predicts that the price of grade A helium would fall (rather than remain unchanged) if more crude were refined and sold as grade A helium.

Although economic studies of the nature of the demand for grade A helium are sparse, there is at least some evidence that the demand is inelastic.[22] Thus, even a small percentage increase in the amount of crude helium which is refined and sold as grade A helium would lead to a much larger (at least three times larger) percentage decrease in the price of grade A helium.

To illustrate this quantitatively, consider the year 1968. In that year about 3.7 Bcf (billion cubic feet) of crude helium were produced (Table 3) and about 0.7 Bcf of grade A helium was sold (Table 4), at a price of about $20 per Mcf.

Suppose that the demand for grade A helium were of unitary elasticity, and that an additional 0.1 Bcf of grade A helium were sold. Then the price in the grade A market would fall to $17.50 per Mcf. If the demand were actually inelastic (instead of unitary elastic), then the price would even be lower than $17.50 with the additional 0.1 Bcf of grade A helium in the market.

The point here is that the additional 0.1 Bcf of grade A helium could be produced by using only an additional 2.7 percent (0.1 Bcf/3.7 Bcf) of the crude helium produced in that year. If larger amounts of crude were refined, the price of grade A would fall

by even more. Yet the 1973 court decision assumes that all of the crude helium could be refined and sold as grade A helium at a price of $20 per Mcf. The large difference in the volumes of helium in the crude and grade A markets therefore render the latter inappropriate as a starting point in the workback method.[23]

In its 1978 decision, the Oklahoma district court recognized these economic principles in changing its starting point for the workback method from the grade A helium market to the crude helium market. It noted that,

> If one fact has clearly emerged at retrial, it is the inappropriateness of using refined [grade A] helium prices as a starting value in extrapolating commingled helium's value at the wellhead . . .
>
> Any suggestion that the helium in this case could have been refined and subsequently sold at then prevailing market prices of $20 to $35 per Mcf is at variance with what the most persuasive evidence demonstrates to be the truth . . .
>
> It is now clear that it would be improper to attempt to value the 34 billion cubic feet of conservation curde [sic] helium in storage by any price the 3.3 billion cubic feet of refined helium [sold to private customers between 1962 and 1973] may have sold for. To do so would require the assumption that all of the 34 billion cubic feet of stored helium could have

been refined and sold in the grade A market. It is clear that such could have not been done without drastically reducing the price of grade A helium.[24]

[brackets added, footnotes omitted]

VI. CONCLUSION

The valuation of an economic resource at a given stage of production can pose an interesting economic problem, particularly if there is no market at that production stage. A workback methodology, properly applied, can be useful as a tool for valuation. However, it should not be applied without an understanding of market structure, a principle correctly recognized by the Oklahoma district court at retrial.

> In developing a resource from a raw material into a finished product, each production stage will add economic value to what was initially only the value of the raw material. The value added at each stage of production is essentially the cost of resources used in taking the material through that stage of production. The work-back method essentially establishes at each production stage the value of the product at that point. By subtracting out all production costs, the value of the raw material is revealed. Application of this approach, however, can be difficult. Market structures vary at different production stages and correlating figures

> from one stage to the next can require abstruse analytical calculations, easily resulting in error. The selected starting point should be as close as possible to the production stage in question.[25]
>
> [Emphasis added, footnotes omitted]

In this paper we have shown how large errors in valuation can result from an application of the workback method if the market structure is ignored, particularly if the starting point involves a much different volume than the quantity at the stage at which the resource is to be valuated. In fact, one federal district court made an error of this type in attempting to determine the wellhead value of helium in a 1973 case, although on remand the same court corrected its error with explicit reference to the economic principles we have relied on in this analysis.

We conclude by emphasizing that the workback methodology has much broader potential use than in helium, or even natural resources alone. Accordingly the principles we have demonstrated and illustrated have a broader application as well. This, more than the lesson about helium alone, should be viewed as the major contribution of this paper.

FOOTNOTES

1. Northern Natural Gas Co. v. Grounds, 393 F. Supp. 949, 992 (D. Kan.).

2. Ashland Oil, Inc. v. Phillips Petroleum Company and United States of America, United States District Court N.D. Oklahoma No. 67-C-238, August 13, 1973 as corrected August 31, 1973.

3. Ashland Oil, Inc. v. Phillips Petroleum Company and United States of America, United States Court of Appeals (tenth cir.), appealed from the United States District Court of Oklahoma (D.C. 67-C-238), May 10, 1977.

4. Helium Study Committee (1978), p. 34.

5. While helium is often found in conjunction with natural gas, it is not always so. For example, the very rich helium sources (about eight mole percent) produced by Kerr-McGee at Navajo, Arizona, were found in a gas stream which was predominantly nitrogen, rather than natural gas.

6. Helium Study Committee (1978), p. 1.

7. An Act to Amend the Helium Act of March 3, 1925, as amended, Public Law 86-777, 86th Congress, September 13, 1960.

8. The Helex companies were: Phillips Petroleum, Cities Service Helex, Northern Helex, and National Helium.

9. See United States Department of Interior (1972).

10. Northern Natural Gas Company v. Grounds, 393 F. Supp. 919 (1974) contains numerous references to contracts at about $2.00 per Mcf.

11. In the 1978 retrial the Oklahoma district court found that: "A $2.00 per Mcf price for commingled helium was used by the Bureau of Mines in computing the price it was willing to pay under the helium conservation program. The four Helex companies in good faith believed they owned the helium contained in the natural gas and accepted $2.00 per Mcf as the value of the commingled helium." See Ashland v. Phillips (1978), n. 20 infra, Judgment, Findings of Fact, para. 34.

12. The private production of crude helium other than that of the Helex companies was primarily that of Helium, Inc. (sometimes called Kansas-Nebraska), and Alamo Chemical and Gardner Cryogenics. The latter was partially owned by Phillips, and sold its helium to Phillips at the relatively low price of about $7.50 per Mcf. Compare this price with the others shown in Table 3.

13. Ashland Oil v. Phillips Petroleum and U.S., Northern District Court of Oklahoma, No. 67-C-238, Phillips Exhibit 44 (1978).

14. The price in each year has been calculated by multiplying the price paid to each Helex company times the fraction of the total volume of crude helium sold to the government by that company; these individual products are then summed to obtain the weighted average price.

15. As posted in the federal register, the price of grade A helium sold by the government to its own agencies was $15.50 per Mcf; government sales to private purchasers were at $19 per Mcf.

16. Ashland v. Phillips (1978), n. 13 supra, Phillips Exhibit 51.

17. The total helium plant costs for Phillips' Sherman Plant ranged from $3.53 to $5.52 per Mcf during the helium conservation program; the costs for Phillips' Dumas plant ranged from $5.91 to $6.55 per Mcf. The value of the incremental liquid hydrocarbons, to be subtracted from the above figures to obtain the net helium costs, were calculated on average to be about $1 per Mcf of extracted helium. Thus we arrive at the $4 per Mcf figure in the text. The correctness of the court's incremental liquid calculation is not treated in this paper, primarily because the magnitude of any error introduced there is of second order importance compared with the error arising from the court's use of an improper starting point.

18. The anomaly is even more pronounced in the 1978 rehearing of the Ashland case. Ashland argued that the appropriate starting point for each year should be the price of grade A helium, approximately as shown in the next to last column of Table 4. Thus, in 1963, for example, the workback method would be started at $35 per Mcf. If the total extraction and refining costs were $4 and $2 per Mcf respectively, the workback price at the Helex plant inlet would be $29 per Mcf, and the total government payment for crude helium would be about $38 per Mcf ($29 - $3 + $12).

19. Ashland v. Phillips (1978), see n. 13 supra.

20. See Ashland Oil, Inc. v. Phillips Petroleum Company and United States of America, Northern District Court of Oklahoma, No. 67-C-238, Judgment filed December 28, 1978, findings of fact para. 22, 23.

21. Ashland v. Phillips, n. 20 supra, conclusions of law para. 8.

22. See Howland and Hulm (1974), section 4.

23. This analysis was made in the author's testimony in Ashland v. Phillips, n. 13 supra, transcript pages 789-794. Also quoted in Ashland v. Phillips, n. 20 supra, Judgment, footnotes 4, 7, and 9.

24. Ashland v. Phillips, n. 20 supra, Judgment, pages 3, 4, and 19.

25. Ibid., p. 3. See also the testimony of Professor Richard H. Leftwich, Ashland v. Phillips, n. 13 supra, transcript pages 368-370, 386, quoted in Ashland v. Phillips, n. 20 supra, Judgment, footnotes 1, 2, and 10.

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