SOCIETY OF PETROLEUM ENGINEERS OF AIME
6300 North Central Expressway
Dallas, Texas 75206

PAPER NUMBER SPE 1018

THIS IS A PREPRINT --- SUBJECT TO CORRECTION

GAS PRORATION IN THE SAN JUAN BASIN

By

Emery C. Arnold, New Mexico Oil Conseration Commission

INTRODUCTION

Natural gas has been produced commercially in the San Juan Basin of Northwest New Mexico since the early 1920's. Development was minor until late 1951, when our first major market was established in California by the El Paso Natural Gas Co. Ninety-five per cent of our natural gas development has taken place since 1951.

As of Jan. 1, 1952, there were about 300 producing gas wells serving local New Mexico and Colorado markets. As of Jan. 1, 1964, there were 5,920 wells producing gas. Total cumulative production to Jan. 1, 1964, was 2,973,010,197 Mcf.

PICTURED CLIFFS SANDSTONE, MESAVERDE FORMATION, AND DAKOTA SANDSTONE

Gas development since 1952 has been at a steady rate of from 300 to 650 wells per year at an average rate of 500 wells per year. Ninety-seven per cent of our gas production comes from three geologic formations, all within the Cretaceous System. These are the Pictured Cliffs Sandstone, Mesaverde Formation and the Dakota Sandstone.

The most important controlling mechanism for the accumulation of gas in each of these formations is rock characteristics. The Cretaceous System in the San Juan Basin consists of thick shale sections with intervening sandstones. Within specified areas, wherever these sandstones develop sufficient porosity and permeability, natural gas has accumulated. For this reason, the occurrence of gas is very wide-spread geographically and the dry hole ratio for development wells is very low.

The Pictured Cliffs Sandstone is the shallowest of the major producing zones and ranges in depth within the producing areas from 1,000 to 4,000 ft. There are 10 Pictured Cliffs Pools as defined by the Oil Conservation Commission, all of which represent sandbar accumulations along buried shore lines. Approximately 2,500 wells are producing from this zone. These wells were all developed on 160-acre spacing. Mesaverde gas production comes from a huge, fairly well defined stratigraphic reservoir which is approximately 70 miles long and 40 miles wide. Depth ranges from 4,000 to 6,000 ft. Approximately 1,900 wells are now producing in the Blanco Mesaverde Pool. This pool is developed on 320-acre spacing and is still not fully developed.

The third major gas producing horizon is the Dakota Formation, which varies in depth from 6,000 to 8,000 ft. within the producing area. The Basin Dakota Pool is defined by the Commission as being that area which is productive of gas from the Dakota in San Juan, Rio Arriba and Sandoval Counties. Most of the productive area is within San Juan and Rio Arriba Counties and encompasses an area of 80 miles long and 50 miles wide. Not all of this area is productive of gas from the Dakota, as there are some isolated areas in which the sandstone becomes too shaly and tight to produce. However, most of this area will eventually produce gas from the Dakota Formation. There are presently about 900 producing wells completed in this formation, most of which have been drilled in the last four years. This pool is also spaced on 320-acre units. Development is still continuing in this pool and it is considerably less than one-half developed.

PRORATION

All San Juan Basin gas was unprorated until 1955. During the early fifties the demand for gas was larger than the supply available. By 1954 supply began catching up with the demand. Studies made by the Commission staff indicated that ratable take was not being accomplished in some instances, either as between operators or pipelines in the same pools. Studies were started by the Commission staff and operator's committees in 1954 in preparation for the inception of proration. From the beginning, it was apparent that there were wide divergences of opinion regarding reserves, both on a total pool basis and an individual proration unit basis. Relatively few core analyses were available. Electric logs or gamma-ray logs were available on most wells, but few companies agreed on the parameters to be used in log interpretation for the determination of porosity, water saturation, effective permeability. The arguments were further intensified by disagreements over what portion of gas in place under a given proration unit represented recoverable gas within reasonable economic time limits.

It is obvious that the accurate determination of recoverable reserves is of prime importance in the selection of a proration formula. Correlative rights cannot be protected unless it is known what each operator in a pool owns. This dilemma has faced the New Mexico Commission from the first proration hearing to the last in the San Juan Basin and the end is not in sight.

Gas proration was first instituted in the San Juan Basin in March, 1955. The first reservoir prorated was the Blanco Mesaverde reservoir, which is approximately 70 miles long and 40 miles wide, and at the time proration was started contained approximately 750 wells. Rock characteristics in this pool are high variable. Permeabilities are generally low and average producing capacities are also low. Deliverabilities range from less than 100 Mcf/D to 20,00 Mcf/D. Porosities, water saturations and net pay thickness also vary widely across the pool and for this reason it was recognized early that some factor in addition to acreage would be needed in the proration formula in order to allocate production in relation to reserves.

Testimony was presented by seven operators with interests in the Blanco Mesaverde Pool. Some of them attempted to show a direct relationship between deliverability and reserves. They contended that the ability of a well to produce reflects better than any other factor the recoverable reserves in place under a proration unit. They contended that recoverable reserves are reflected by total effective permeability of the pay section, porosity, connate water saturation and that these factors and deliverability tend to show a straight line relationship. These people advocated a 100 per cent acreage times deliverability formula. Other formulas proposed were: Seventy-five per cent deliverability times acreage plus 25 per cent acreage; 50 per cent deliverability times acreage plus 50 per cent acreage; 25 per cent deliverability times acreage plus 75 per cent acreage; and pressure times acreage. Estimated reserve ratios between proration units in the pool varied from 3 to 1, to 46 to 1. This wide variation in reserve estimates reflects the small amount of reliable reservoir data available for the Blanco Mesaverde Pool. This lack of information resulted largely from the employment of completion techniques which made reservoir data difficult to obtain. The use of gas as a drilling fluid also limited the types of electrical surveys which could be conducted at that time.

Purchasers in the Pool requested that special consideration be given the generally low average capacity of wells in the Blanco Mesaverde Pool. It was pointed out that it was their particular problem to meet market demand as the market exists on a day-to-day basis. It was maintained that a formula based predominantly on deliverabilty would provide much better flexibility in meeting market demand.

PRORATION FORMULA

As the result of this hearing the Commission issued Order R-128-C in Dec., 1954. This order established a proration formula in the Blanco Mesaverde Pool based 25 per cent on acreage and 75 per cent on acreage times deliverability. Balancing dates were fixed on a six-months basis between Feb. 1 and Aug. 1 of each year. Provision was made for under production or over production accrued during a proration period to be made up during the next period. At the end of a balancing period, any underagewhich has been carried through the period is cancelled and the total cancelled underage is then redistributed to all non-marginal wells inthe pool. Any overage carried through a period must be curtailed at the end of the period.

Early difficulties with the proration formula resulted from differences in certain wells' actual producing ability against existing line pressures and the wells' calculated deliverability as determined from the deliverability test. These difficulties resulted in the accrual of large underages to certain wells which were unable to produce their allowables under existing conditions. To alleviate this condition, the order was later amended to better define marginal wells. This amendment states: "Any well which enters a proration period and fails to make its allowable during at least one month of the ensuing period shall be classified as a marginal well and have its accrued underage cancelled and redistributed." The amendment further states: "The allowable assigned a marginal well shall be equal to the maximum production during any month of the preceding gas proration period. The pool allowable remaining each month after deducting the total allowable assigned to marginal wells shall be allocated among the non-marginal wells entitled to an allowable. No marginal well is permitted to accumulate under production. If at the end of a proration period a marginal well has produced more than the total allowable for the period assigned to a non-marginal well of like deliverability and acreage, the marginal well shall be classified as a non-marginal well and its allowable and net status adjusted accordingly"

Subsequent to the hearings held in the Blanco Mesaverde Pool, hearings were held and proration orders written for six Pictured Cliffs Sandstone pools. These are shallower reservoirs which are similar to the Mesaverde reservoir insofar as rock characteristics are concerned. These pools are also stratigraphic accumulations. The 25 per cent acreage plus 75 per cent acreage times deliverability formula was instituted in each of these pools without controversy.

In Oct., 1960, as hearing was called on the Commission's own motion to prorate the Basin Dakota Gas Pool. This gas reservoir is also similar to the Blanco Mesaverde reservoir in that it is a relatively low permeability sandstone reservoir, average producing capacities are low, production is widespread geographically. Production occurs from a common stratigraphic trap, over an area 80 miles long and 50 miles wide. Gas occurs in separate sand units in different parts of the field, but these sand units overlap and interfinger so that separate pool delineations would be impossible even though intercommunication between various segments of the pool is imperfect.

The 25 per cent acreage plus 75 per cent acreage times deliverability formula was also instituted in the Basin Dakota Pool. A provision was written in the order calling for a hearing later to review the need for minimum and maximum allowables.

PROPOSED FORMULA CHANGES

Early in 1962, an application was filed by the Consolidated Oil & Gas Co. to change the proration formula in the Basin Dakota Pool to a formula utilizing 60 per cent acreage plus 40 per cent acreage times deliverability. The matter was set for hearing in April, 1962. Proponents of the formula change presented evidence indicating that the reserve ratio of commercial wells in the pool was approximately 3 to 1, whereas the allowable ratio in some cases was as high as 20 to 1. They presented a tabulation showing that 58.8 per cent of the wells in the pool had a deliverability between 0 to 1,000 Mcf/D and 80 per cent had a deliverability of less than 2,000 Mcf/D. Their tabulation showed that wells of over 6,000 Mcf/D deliverability received 12 times as much allowable per well as wells in the 0 to 1,000 deliverability group. General reservoir information was alos presented indicating that changes in the characteristics of the reservoir occurred gradually across the reservoir and not abruptly from location to location. They contended that very little, if any, correlation could be made between deliverability and reserves in place under a tract. The proponents for a change also contended that approximately 50 per cent of the wells in the pool were economic failures, not because of lack of recoverable reserves or ability to produce commercially, but because of assigned allowables under the 25 per cent acreage plus 75 per cent acreage times deliverability formula. In summary, their testimony was to the effect that correlative rights were being violated because the allocation formula in use had failed to allocate to most wells an allowable even approximately commensurate with their reserves in place.

The oppents to a change in allocation formula presented evidence which they concluded showed a direct relationship between deliverability and reserves in the Basin Dakota Pool. One operator presented reserve information of 457 wells. In calculating reserves 65 core analyses were used which were from wells scattered across the field. Porosity, water saturation and residual gas saturation were determined from these cores and the values were averaged on a township basis. Using this information with pressure, temperatures and gravity from individual wells an Mcf/acre-foot value was determined. This was then multiplied by the net pay figure taken from individual electric logs and by proration unit acreage to fix individual well reserves. These reserves were grouped by reserve range and deliverabilities for the wells in each reserve range were averaged and reserves were then plotted against deliverabilities to show the relationship between the two.

Subsequent to the April, 1962 hearing in the Dakota proration case, but prior to the issuance of an order in the case, the New Mexico Supreme Court handed down its decision in the Jalmat Gas Proration Case.

In this case, the Commission in 1958 had changed the proration formula in the Jalmat Gas Pool in Southeastern New Mexico from straight acreage to 25 per cent acreage plus 75 per cent acreage times deliverability. The Order was attacked in the Courts by several operators in the pool. The district Court affirmed the Commission's order and the decision was appealed to the State Supreme Court. The Supreme Court reversed the Commission's order and ordered the Commission to revert to the straight acreage formula in prorating the pool. In its decision, the Court specifically outlined the procedure the Commission must follow in prorating a gas pool as the following excerpt describes:

> "The Commission was here concerned with a formula for computing allowables, which is obviously directly related to correlative rights. In order to protect correlative rights it is incumbent upon the Commission to determine sofar as it is practical to do so certain foundationary matters, without which the correlative rights of the various owners cannot be ascertained. Therefore, the Commission by 'basic conclusion of fact' (or what might be termed findings) must determine insofar as it is practicable (1) the amount of recoverable gas under each producer's tract; (2) the total amount of recoverable gas in the pool; (3) the proportion that (1) bears to (2); and (4) what portion of the arrived at proportion can be recovered without waste."

The decision further states: "We therefore find that the order of the Commission lacked the basic findings necessary to and upon which jurisdiction depended, and therefore Order No. R-1092-C and Order No. 1092-A are invalid and void. We would add that although formal and elaborate findings are not absolutely necessary, nevertheless basic jurisdictional findings supported by evidence are required to show that the Commission has heeded the mandates and the standards set by the Statutes. Administrative findings by an expert administrative commission should be sufficiently extensive to show not only the jurisdic ion but the basis of the Commission's orders."

Faced with the Supreme Court's decision, the Commission had no alternative but to deny the application for formula change in the Basin Dakota Pool. This they did with the finding that the evidence presented at the hearing concerning recoverable gas reserves in the pool was insufficient to justify any change in the allocation formula.

<u>REHEARING</u>

Consolidated Oil & Gas was granted a rehearing and certain reserve information was subpoenaed from individuals and companies by the Commission. Information subpoenaed consisted of core analyses, electrical logs and well records of wells in the Basin Dakota Pool.

The case was reheard on Feb. 14, 1963. The applicant proposed that the existing order was void on the basis of the Jalmat decision, as the original order was based solely on a finding that there is some general correlation between deliverability and reserves and was not based on a tract-by-tract analysis as required by the Jalmat decision. Consolidated presented a tabulation of reserves which they arrived at by using the 460 wells presented by El Paso Natural Gas Co. in the April hearing. They stated that they had confirmed individual well reserves by using core analyses and logs from 58 wells on which core analyses were subpoenaed. From their study of these 58 wells they came within range of 70 per cent to 130 per cent of the original reserve figures presented by El Paso Natural Gas Co. From this they concluded that El Paso's reserves for the original 460 wells were representative and used them without modification. They then spotted these 460 wells on a map and contoured lines of equal reserves on the map. An outer limit of one billion cu ft per 320-acre drill block was used on the grounds that anything drilled beyond this limit would be an uneconomic well. Later drilled wells were then placed on the contour map and their reserves were assigned from the contours. The number of marginal wells in the pool was determined from the Dec., 1962 gas proration schedule and all other wells were considered non-marginal wells. Out of a total of 743 wells in the pool at that time, 699 wells fell into the non-marginal category. They then determined the total recoverable reserves in the pool and the recoverable gas under each 320-acre tract which had a well located on it.

This study showed the total pool reserve to be 2,225,000,000 Mcf, total reserve exclusive of marginal wells to be 2, 159,000,000 Mcf, average reserve per 320-acre proration unit to be 3,300,000 Mcf, average deliverability all wells to be 1,340 Mcf/D, average deliverability for non-marginal wells to be 1,410 Mcf/D. The percentage of total pool reserve attributed to each proration unit was then determined. Using Dec., 1962, total allowable and the deliverabilities for the wells in the pool, allowables were then calculated with formulas having from 100 per cent to 0 per cent deliverability in 10 per cent increments as the deliverability factor. Each well's percentage of total allowable under each formula was then determined. The percentage of total allowable that each well received under each formula was then compared with each well's percentage of total reserve. When this allowable reserve ratio equalled one they concluded that the well was receiving exactly the proper amount of allowable to enable the well to produce the amount of gas under its tract, at least for that particular set of market and deliverability conditions. In order to attain a more definitive analysis, the wells were grouped in allowable-reserve factor groups. The limits on the "proper allowable" group were fixed at 0.7 to 1.3. They concluded that this degree of accuracy paralleled the accuracy which could be attained in volumetric reserve calculations in the Basin Dakota Pool. The wells which received an allowable which placed them in the 0.7 to 1.3 A/R group were then counted for each formula. The formula which placed the maximum number of wells in this group was deemed to be the proper formula.

Opponents of the formula change challenged the accuracy of the reserves used by the applicant in their study. They maintained that reserves had been assigned to many proration units which were not in reality recoverable reserves. Exhibits were presented which were designed to show recoverable gas in place. These exhibits were based upon a pressure decline versus productivity study which resulted in the conclusion that many wells would be abandoned at relatively high abandonment pressures.

REVISED ALLOCATION FORMULA

Based upon the evidence and testimony taken in Case 2504 the Commission issued Order R-2259-B on July 3, 1963. This order established an allocation formula based 60 per cent on acreage and 40 per cent on acreage times deliverability in the Basin Dakota Pool. The effective date of the order was set Aug. 1, 1963.

The opponents to the change in the allocation formula immediately made application to the Commission for rehearing. These applications were denied and a case was filed in San Juan County District Court attacking the order. This case was heard in March, 1964, and the court affirmed the Commission's Order. The case has now been appealed to the New Mexico Supreme Court.

Following the issuance of Order R-2259-B the Commission staff has made a continuing study of the allocation formula in the Basin Dakota Pool using various market demands. Figs. 1 through 4 illustrate a study that was made using a market demand of 10,308,000 Mcf, which was the production for the pool Dec., 1962. In this study, the breaking point method was used in defining marginal wells. Using this method, no well is assigned an allowable larger than its calculated deliverability. As the relative percentage of acreage in the formula increases, the number of marginal wells increases as an increasing number of wells are assigned an allowable larger than their calculated deliverability.

CALCULATED ALLOWABLES

In studying Fig. 1, it should be remembered that two factors are constant, the market demand and each well's percentage of reserve factor. Allowables were calculated using from 100 per cent to 0 per cent deliverability in the allocation formula in 10 per cent increments. Under each formula, the allowables assigned to individual wells change, and this results in a change in the wells' allowable-reserve ratio. This causes a shift of wells from one allowable-reserve group to another. The total allowable assigned to the wells in each allowable-reserve group for each formula was then totaled and plotted. The curves then illustrate, for each separate acreage-deliverability formula, the amount of pool allowable assigned to wells receiving too much, too little or the proper amount of total pool allowable. The "proper amount" of allowable as here used means that a well is receiving a percentage of pool allowable which is within 30 per cent of its percentage of total pool reserve.

Fig. 2 is identical with Fig. 1, except that the percentage of pool wells in each allowable-reserve group for each formula is plotted rather than the percentage of pool allowable assigned to these wells.

Fig. 3 is a plot of the percentage of allowable received by those wells which for each allocation formula receive 50 per cent or more too much allowable. These groups are further subdivided into allowable-reserve groups of 1.5 to 1.7, 1.7 to 2.0 and 2.0 and up. Fig. 4 shows the same information on a percentage of wells basis. It should be noted that when a deliverability factor of 75 per cent is used, nine per cent of the wells in the pool, all receiving in excess of twice their proper allowable, receive 25 per cent of the total pool allowable. This is indicative of the fact that there are a small percentage of extremely high deliverability wells which are being assigned allowables many times in excess of their proper allowable when a 75 per cent deliverability factor is used. This condition is alleviated when the deliverability factor used in the formula is reduced. At the point on the curve where a 40 per cent deliverability factor has been used, six per cent of the wells in the pool have an A/R factor of two or larger, and those wells are allocated 11 per cent of the pool allowable. It is also interesting to note that the low point on the curve representing wells with an A/R factor of 2.0 or greater occurs at the point where a 20 per cent deliverability factor is used. Beyond this point, both the percentage of wells and percentage of pool allowable assigned to wells receiving more than twice their proper allowable increases. This demonstrates the inequity of a straight acreage formula as it is obvious that this formula is assigning to a considerable number of low reserve wells an excessive amount of allowable.

CONCLUSIONS

If acreage and deliverability are to be the factors used in a proration formula then the soundness of the approach used in the Basin Dakota Case is apparent. It is also apparent that no acreage-deliverability formula will give to all wells in the pool their proper allowable. A compromise must be made on the formula which most nearly gives a proper allowable to the greatest number of wells. Strictly from the standpoint of the protection of correlative right, the conclusion is reached that possibly the best way to assign allowables would be to use only the percentage of reserve factor. The difficulty in this, of course, aside from administrative difficulties in assigning allowables, is the determination of reserves using the volumetric approach. Much better reservoir information on each well would be needed than has been available on many wells in the past in order to arrive at an aggreable percentage of reserve factor on each well. Reserve analysis using the volumetric approach is in many cases an abstract science and it would place in the hands of the person assigning allowables an uncommon amount of discretion.

Of course, the validity of the Commission's present order is also dependent upon the accuracy of reserves used in the study. It is certainly probable that the reserve figures used were accurate within 30 per cent and if so the conclusions reached are sound, as greater accuracy would not have materially changed the results of the study.

Undoubtedly, in future proration cases in the San Juan Basin, either on new pools or for proposed changes in older pools, a similar approach will be used, as it would seem that the Supreme Court decision in the Jalmat Case makes such an approach mandatory.

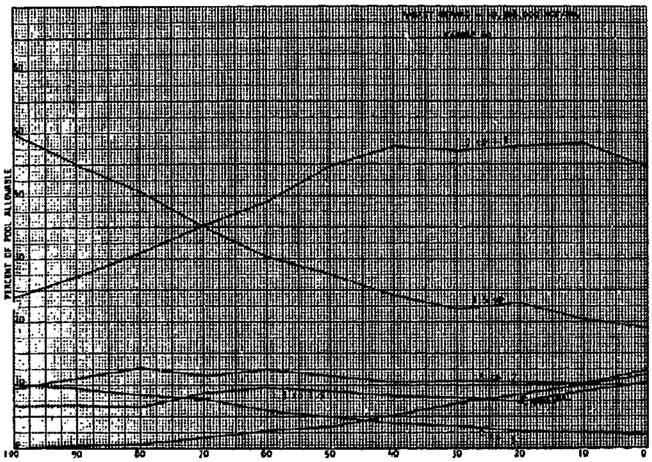
CHART INTERPRETATION NOTES

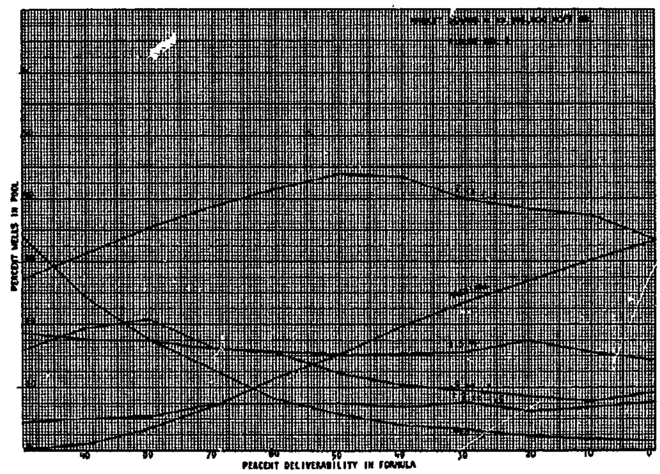
(A) The basic formula for which the allowable vs. reserve relationships were computed is known as an acreage times deliverability plus type formula, i.e., 30 per cent plus 70 per cent acreage times deliverability.

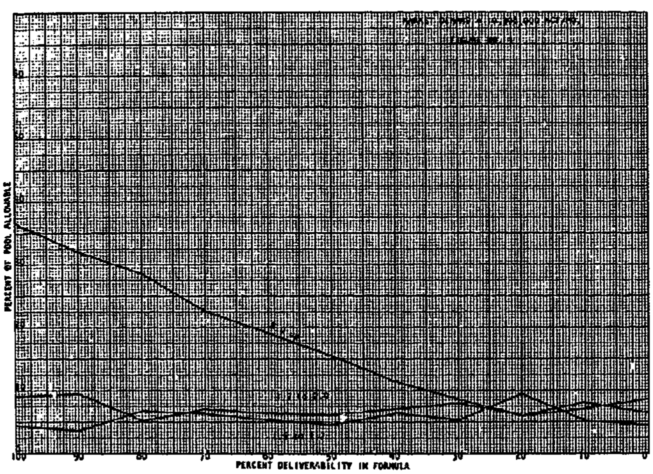
(B) The plots shown on the following graphs show various "A/R factor" groups of wells where the percentage relationship of acreage and deliverability vary in the formula by 10 per cent increments.

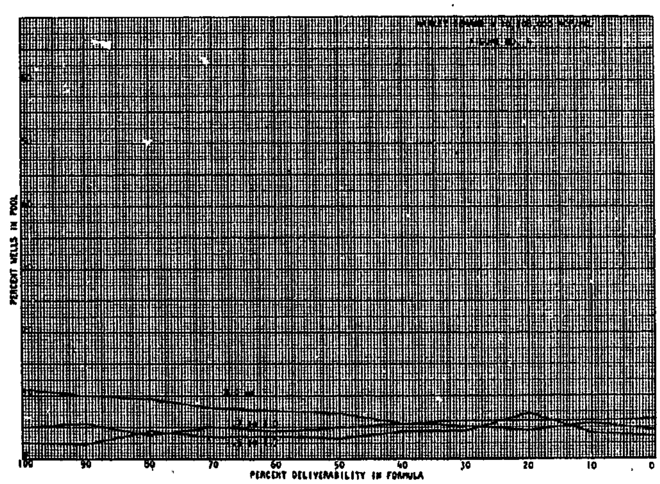
(C) A/R Factor= A ratio of a well's percentage of pool reserves.

It would follow then that an A/R factor of less than one (1.0) shows the well is receiving less than its share of allowable and an A/R factor of more than one (1.0) shows the well is receiving more than its share of allowable.


PERCENT OF POOL ALLOWABLE
100
90
80
70
60
50
40
30
20
10
0


PERCENT WELLS IN POOL
PERCENT DELIVERABILITY IN FORMULA


PERCENT OF POOL ALLOWABLE
PERCENT DELIVERABILITY IN FORMULA


PERCENT WELLS IN POOL
100
90
80
70
60
50
40
30
20
10
0
PERCENT DELIVERABILITY IN FORMULA