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# THE INFLUENCE OF NORTH DAKOTA'S CONSERVATION PROGRAM ON THE DEVELOPMENT AND UNITIZATION OF THE NORTH TIOGA-MADISON POOL

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## ABSTRACT

The North Tioga-Madison pool was created, administratively, when the Tioga-Madison unit was formed in 1958. Wells not included in the Tioga unit, together with an outpost well, were defined as producing from the North Tioga-Madison pool. In order to speed development of the pool, and obtain data necessary for the initiation of secondary recovery operations, wide spacing was prescribed and proved effective. Studies indicated primary recovery of 9.5 million bbl and additional recovery of 28.1 million bbl from pressure maintenance. Delays in the initiation of the unit operation caused the Industrial Commission to restrict production from the pool pending commencement of fluid injection. Disagreements between operators and failure to compromise these differences have been reflected in failure to secure 100 per cent participation of royalty interests, making it impossible to carry out a completely effective project. As a result total ultimate recovery is expected to be less than 30 million bbl, illustrating the necessity of including provisions for compulsory unitization in all oil and gas conservation statutes.

The history of this reservoir points up the desirability of closer cooperation between industry and the regulatory bodies, particularly the technical staffs, and the authors propose a new approach to the problem.

Illustrations at end of paper.

## INTRODUCTION

The North Tioga area has been selected as a case history in oil conservation, since many of the procedures and policies now in use were first used here or were promulgated as a result of something which happened here. Its history also points up the very real need for a new approach to the problem of organizing cooperative projects for the supplementation of reservoir energy.

The first Madison oil reservoir in the Williston Basin was discovered in the Tioga field by Amerada's No. 1 Oscar Bakken well in April, 1952. The earlier discovery in the Iverson well had been in the Devonian and Silurian; Madison shows in that well were not noted. After the completion of the initial Madison well in the Tioga field, it developed rapidly on 80-acre spacing.

A previous request for 80-acre spacing in the Beaver Lodge field, made by Amerada and Hunt, had been denied by the Commission in Jan., 1952. The denial was based on the scarcity of technical evidence and the opposition posed by landowners who shared the commonly held belief that 80-acre spacing could not properly drain the

area. Under North Dakota statutes, in effect at the time, the proper location for wells was the center of a quarter-quarter section or governmental lot corresponding thereto. Since this represented a minimum spacing, it did not preclude the development from proceeding on an 80-acre pattern if demands for offset wells could be disposed of satisfactorily. The operators in the Tioga field elected to pursue this course and 298 producing wells were completed within the Tioga field limits with only four exceptions to the 80-acre pattern.

In July of 1954 the Commission had called, on its own motion, a second hearing on the matter of well spacing for the Tioga field. At the time of the hearing data from 135 wells was presented and clearly indicated that 80-acre spacing would drain the recoverable oil from the pool and the Commission so ordered.

The Commission's orders in such cases followed a relatively standard pattern. The land subdivisions which were to comprise the pool were described, thus establishing lateral boundaries within which the special field rules would apply.

A fifth exception brought about the creation of the so-called "buffer zone" which is now used in North Dakota, and about which there has been considerable discussion. In this case an operator applied for a permit to drill a well 660 ft from the east boundary of the field as a direct offset to a producing well in the field. The application was received on April 5, 19 .

The applicants for the exception location argued, logically, that outside of these boundaries the state-wide rule of 40-acre spacing would apply. Since no rules or regulations existed under which such an application could be denied, the Commission granted the permit.

Henceforth the Commission's spacing orders would include a provision for automatic extension of the field limits to include a producing well drilled as an extension to a pool. An amendment to the rule relative to drilling permits was also passed. This amendment gave the State Geologist discretion to deny a permit if, in his opinion, the well drilled in the location applied for would cause waste or violate correlative rights.

In order to administer this new provision with some degree of uniformity the State Geologist requested and received a statement of policy from the Commission which created a zone around each field, 1-1/2 miles in width, where wells should be drilled on the pattern prevailing in the field. The arrow in Fig. 1 points to the well which brought about this situation. It is now an injection well in the North Tioga unit.

## HISTORY OF DEVELOPMENT

The North Tioga field, located in Williams, Burke and Divide Counties, North Dakota, was created administratively on Sept. 6, 1958, following a public hearing before the North Dakota Industrial Commission.

The southern portion of the new field had previously been included within the Tioga field, but following the unitization of a portion of that field there existed a group of wells, not included in the unit, which, according to the data accumulated by the Tioga Field Technical Committee, were part of a separate pool.

Fig. 1 shows the area as developed on Sept. 1, 1958. The solid line delineates the area of the Tioga unit and the dotted, curved line represents the zero reservoir volume line as drawn by the operators's committee. The dashed line indicates the limits of the Tioga field at the time.

Fig. 2 shows the new field created at the Sept., 1958 hearing. It was designated the North Tioga field and comprised all of the wells previously included in the Tioga field, but excluded from the Tioga unit, plus some additional area to the north which the operators felt would prove to be productive from the Madison reservoir. Spacing for the new field was set at 160-acres per well for a temporary period of two months. In December this order was extended for a year.

At the hearing the operators had indicated that, if the 160-acre spacing recommendation was adopted, they would proceed with diligence to develop the field, establish its limitations, and collect the necessary information on which to form a unit for energy supplementation. During the following year 38 additional producing wells were completed bringing the total to 74.

Fig. 3 shows the North Tioga field as it existed on Jan. 1, 1960. Here was undeniable vindication of the Commission's decision on spacing. The limits of the field had been reasonably well defined by dry holes and marginal producers; participation in production by owners of royalty interests in the pool was almost complete; and all this had been accomplished within the space of 12 months. The investment in the field was about half of what it might otherwise have been.

## FORMATION OF THE NORTH TIOGA UNIT

The North Tioga Technical Committee began its work on Dec. 2, 1958. The Madison reservoir in the North Tioga field is a solution gas reservoir with a 17 per cent natural water replacement. Porosity ranges from less than 1 per cent to 24 per cent with higher porosities generally occurring in the Midale interval. Permeabilities are generally less than 1 md with some fractured samples showing more than 5,000 md. The Madison reservoir, at a temperature of 160F, yields a green oil with a pour point of less than 5F. As

produced, the oil has an API gravity of 41.5 and a sulphur content of 0.25 per cent. It was determined that a water injection program supplemented by propane injection would increase the ultimate recovery from the Madison reservoir from 9.5 million bbl, by primary methods, to 37.6 million bbl. Of the additional 28.1 million, 10.3 million would be attributable to the miscible phase injection.

An ultimate recovery of 37.6 million bbl would represent a bit more than 62.5 per cent of the original oil in place [STO]. This figure might seem overly optimistic to those who are accustomed to the normal recoveries postulated for the Mid-Continent area; but it is representative of the type of response the Madison reservoirs in the Williston Basin show to energy supplementation techniques.

The source of water for injection was to be the Dakota formation of Cretaceous age to which produced water would be added. Propane for the miscible phase of the program would be obtained from a plant which would be built in the area to process wet gas from the field.

Participation was calculated on the basis of 50 per cent acre-ft and 50 per cent productivity. In determining productivity 84 B/D was set as top capacity, since it was predicted that this would be about the average allowable for wells in the field under state rules. Actual production tests taken over a 30 day period on each well in the field would establish this factor.

Geologic studies of the reservoir indicated that there were two intervals of porosity which were productive. The lower, porous interval was referred to as the "Main Pay" while the upper interval was termed the "Midale" [a stratigraphic term applied to a member of the Madison formation]. The principal porous interval occurs in a yellow-brown, fine, fragmental limestone consisting, in part, of small, rounded algal grains. It is separated from the upper, Midale, porosity by a thin, fractured zone of dark brownish-gray, argillaceous, fossiliferous limestone. The Midale porosity occurs in a yellowish-gray, argillaceous limestone. The Midale interval, while more extensive, is thinner than the Main Pay interval in most cases. All but four of the wells in the pool, at the time, were completed in the Main Pay interval only. The question of the relative value of the two producing intervals was to precipitate a long, and sometime acrimonious, debate.

The formula for calculation of participation factors was set forth in the directive issued by the Operators's Committee to the Technical Committee. The determination of the actual thickness of pay for each tract was left to the Technical Committee.

The question of gross vs net pay thickness was resolved in favor of the gross pay approach, but the agreement was far from unanimous. Although the use of net pay would more nearly reflect a true relationship between the value of the various tracts, its determination would have required a foot-by-foot appraisal in each well and a general agreement as to "cut-off" values.

Additional controversy arose over the relative values to be assigned to the Midale and the Main Pay. The final solution was to use 20 per cent of the thickness between the top of the Midale and the top of the Main Pay, plus the total thickness between the top of the Main Pay and the oil-water contact to obtain the gross pay interval for each well.

Although these would seem to be relatively minor points, in view of the substantial increase in ultimate recovery and income to be obtained, they engendered a great deal of ill feeling between operators and delayed the formation of the unit for some time.

After having required almost 29 months to complete its assigned tasks, the Technical Committee finally submitted the Unit Agreement to the operators in April, 1961. A hearing was held before the Industrial Commission in June, 1961 to obtain approval of the Unit Agreement and Unit Operating Agreement. They were approved as being in the public interest and protective of correlative rights.

Fifty working interests owners, representing approximately 90 per cent of the Unit, ratified the agreement, while 14 working interest owners refused. Since the agreement required approval by 95 per cent of the working interest it appeared that the project would fail to be ratified by the termination date, Sept. 1, 1961. Due to the lack of working interest participation, efforts to obtain royalty interest approval were suspended in July.

At this point it should be noted that the North Dakota Conservation statute makes no provision for compulsory unitization. All units formed must be voluntary in nature, although provision is made for their approval by the Industrial Commission. Such approval serves only as a bar to anti-trust prosecution, and there is a considerable body of legal opinion which holds that such approval is not necessary.

In spite of its lack of authority in this respect the Industrial Commission is vitally interested in unit operations, since they provide the only means of obtaining maximum ultimate recovery. When word of the impending failure of the attempts to unitize the North Tioga field reached the Commission, they called an informal meeting of the working interest owners in an effort to mediate the differences between them, without visible success.

By a vote of the working interests the termination date was extended six months, to March 1, 1962. The ratification necessary to make the unit effective was obtained at 15 minutes to midnight on Feb. 28, 1962; only 15 minutes before the agreement would have expired. As set forth in the agreement it was declared effective on April 1, 1962, but 40 months had elapsed since the first meeting of the operators. On the effective date 66-2/3 per cent of the royalty interest had been committed to the unit.

## SUBSEQUENT HISTORY

The unit operator then applied to the Commission for permission to inject fluids into the reservoir and the hearings were held in April and June of 1962. At these hearings the unit operator testified that 524 of the 579 separate royalty owners had signed, representing about 70 per cent of the royalty interest. Although the unsigned interests were so located as to limit injection operations, if not preclude them entirely, the operator requested the permission necessary to proceed with a limited injection program if feasible.

Fig. 4 shows the limits of the reservoir as determined by the Technical Committee [the curve dashed line], the area originally proposed for inclusion in the unit [the dashed line], and the area finally included [the heavy solid line]. The shaded area within the unit boundary indicates the tracts in which the royalty interest is still uncommitted. It was originally planned to include the entirety of any tract, covered by a single lease, which contained any portion of the reservoir, no matter how small. The present unit contains only 85 of the 102 tracts originally proposed for inclusion.

Fig. 5 is a structure map contoured on the top of the Main Pay interval. The shaded areas again represent tracts having uncommitted royalty interests. The locations of the proposed water injection wells are indicated by the standard symbol. The small triangular symbol indicates the location of the proposed propane injection well.

It can be seen that the proposed propane injection well is located on one of the uncommitted tracts which makes it virtually impossible to carry out that portion of the project. Because of this situation it is estimated that the ultimate recovery from this reservoir will be at least 10 million bbl less than it should be.

On April 27, 1962, the Industrial Commission issued Order No. 540 granting permission to inject "water, gas, and/or other substances" into the Madison reservoir in the North Tioga field. The inclusion, in this order, of a provision limiting production from the reservoir until injection operations were undertaken, marked another milestone in the development of North Dakota's conservation program.

The original reservoir pressure, at a datum of -5,500 ft, was 3,475 psig. The pressure declined uniformly to 2,839 psig in April, 1961. Projection of the established decline indicated that the bubble point, 2,756 psig, would be reached about Jan. 1, 1962. A pressure survey in Nov., 1961 confirmed this prediction. Average pressure was 2,758 psig, only two pounds above saturation pressure. At this point the FVF was was 1.935 and the viscosity of the oil in the reservoir was 0.18 cp.

The next survey in April, 1962 resulted in an average pressure of 2,523 psig. Between April and Nov., 1961, withdrawals from the reservoir averaged 5,318 BOPD, or 65.65 BOPD/pound of pressure decline. Between Nov., 1961 and April, 1962, the withdrawals averaged 5,348 BOPD [almost exactly the same as during the previous period], but production/pound of pressure drop was only 22.75 BOPD. This sharp break in the pressure decline caused the Commission to include in its order a provision limiting withdrawals of oil from the reservoir to 2,000 B/D until the time when the volume of fluids injected into the reservoir reached twice the volume of fluids withdrawn.

This provision was immediately assailed as an attempt on the part of the Commission to force the dissenting royalty interest to sign the unit agreement. Careful perusal of the paragraph of the order in question reveals that the conditions for the suspension of the restriction had no relation to the status of unit ratification.

Water injection began on Dec. 1, 1962 in 10 wells. The volume injected during the first month was 169,741 bbl. An additional well was added during May, 1963, and another in Jan., 1964. The volume of water injected during Feb., 1964, was 348,048 bbl. Withdrawals in February totaled 65,153 bbl of water, 94,260 bbl of oil, and 132,907 SMCF of gas.

Fig. 6 is a performance chart for the unit. The graph of reservoir pressures indicates that injection has become effective during the latter part of 1963. The November survey indicated that the average pressure at datum was only 50 psig below saturation pressure. The GOR's climbed slowly from 1959, but tests made this spring have indicated that GOR's are now dropping.

## SUMMARY

It is expected that the project will reach the limit of its present capability during the coming summer. Injection wells are now operating at or near capacity. Although all working

interests are now committed to the unit, about 24 per cent of the royalty interest remains unsigned. Until key portions of the uncommitted interests are obtained further progress, particularly the miscible phase project, is impossible. It is hard to realize that, with the present state of technical knowledge regarding the mechanics of oil and gas reservoirs, we must sit idly by and watch 10 million bbl of a vital, natural resource go to waste.

In summary, the history of the North Tioga-Madison reservoir points up the vital need for close cooperation between all interested parties including the state regulatory body. The extensive delay occasioned by the debates in the technical committee caused the entire project to lose momentum. We have noted the results.

Lacking the statutory authority to require participation in such cooperative projects for the supplementation of reservoir energy, the regulatory body is unable to achieve its primary objective of maximum ultimate recovery. Without such authority in the regulatory body a small interest, properly situated, can prevent other interest owners from realizing maximum benefits from their property.

## CONCLUSIONS

We believe that authority to require participation in cooperative projects for the supplementation of reservoir energy, together with the authority to prescribe well spacing patterns and to limit the rate of fluid withdrawal are the foundations of a sound and workable conservation program.

Such a program must be administered by men of wisdom, working with a competent professional staff. Since the interests of everyone, the operator, the landowner, the mineral owner, the consumer, the state and the nation are inextricably bound together, there must be complete cooperation and mutual respect between all parties.

The regulatory body must be kept advised of progress and developments at all stages of the operations. If Federal interests are involved, then the USGS personnel must be included in the distribution of such information. The operators must maintain close liaison with the land and mineral owners so that they will be fully informed as to their role in the over-all development. The state regulatory staff must stand ready to supply data and to answer inquiries.

As soon as it has been determined that energy supplementation will be necessary to achieve maximum recovery, the negotiations must be entered into and carried out with a minimum of delay. The regulatory body can be of considerable assistance in the following way:

1. Establish wide spacing for the period of initial development.
2. Establish a schedule of reservoir tests which will provide complete and accurate information on pressures, GOR's, fluid distribution, fluid characteristics and geologic factors.
3. Provide educational material to acquaint all interested parties with the purpose of, and the reason for, energy supplementation.
4. Provide prompt approval when such projects are shown to be in the public interest and protective of correlative rights.
5. Exhibit willingness to accept new equipment and instrumentation when it is available and to approve new methods and techniques as they are developed.

If we all work together in the future it will never again be necessary for anyone to appear before a group such as this and admit to being powerless to carry out a fully effective conservation program.

In the final analysis no conservation law, however well drawn, however well administered, can achieve its full purpose without some provision for treatment of a reservoir as a single mechanical unit. When technical evidence indicates to the regulatory body that unit operation is required, it should be empowered, by law, to enforce such a provision in order to protect these valuable and irreplaceable natural resources.

## ACKNOWLEDGMENT

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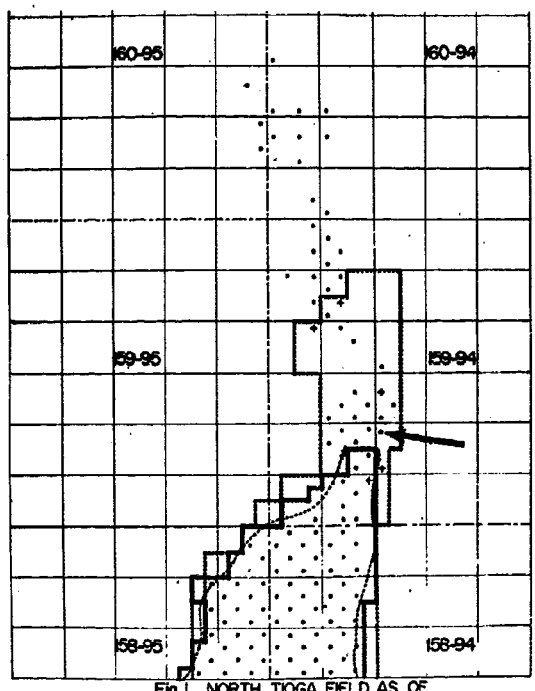

Fig. 1 NORTH TIOGA FIELD AS OF SEPTEMBER 1958

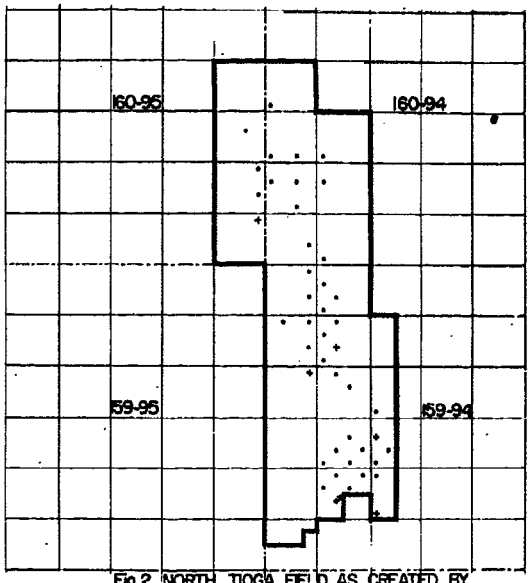

Fig. 2 NORTH TIOGA FIELD AS CREATED BY SEPTEMBER 1958 HEARING

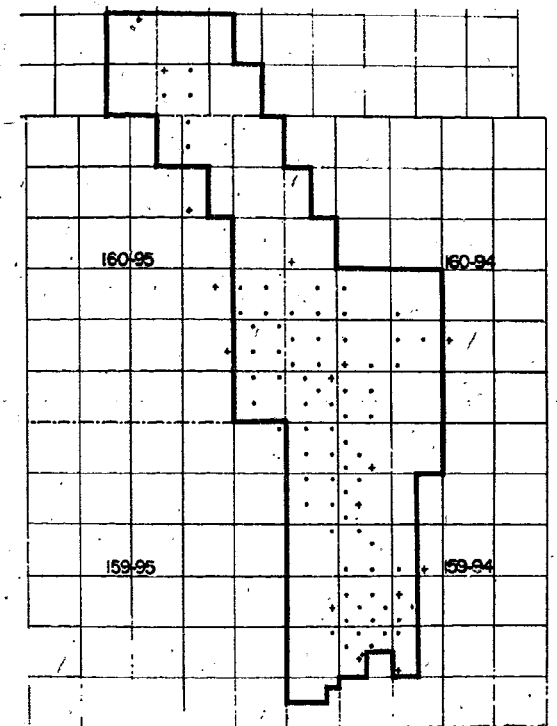

Fig. 3
NORTH TIOGA FIELD AS OF JANUARY 1960

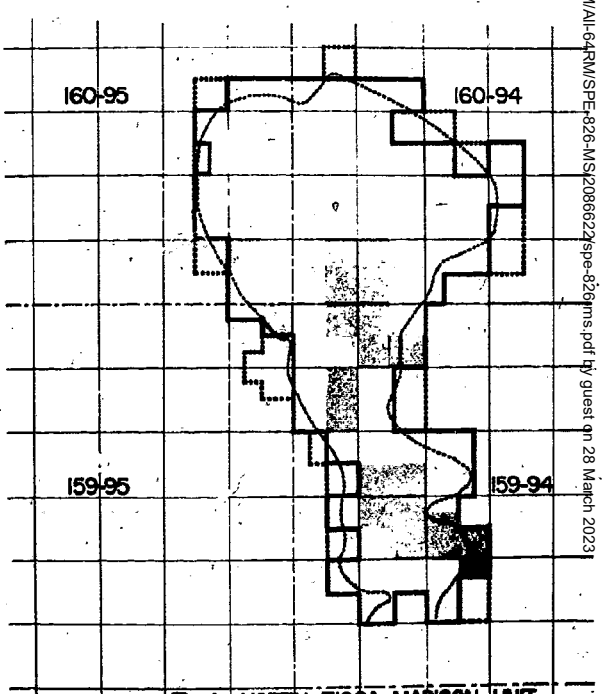

Fig. 4 NORTH TIOGA-MADISON UNIT

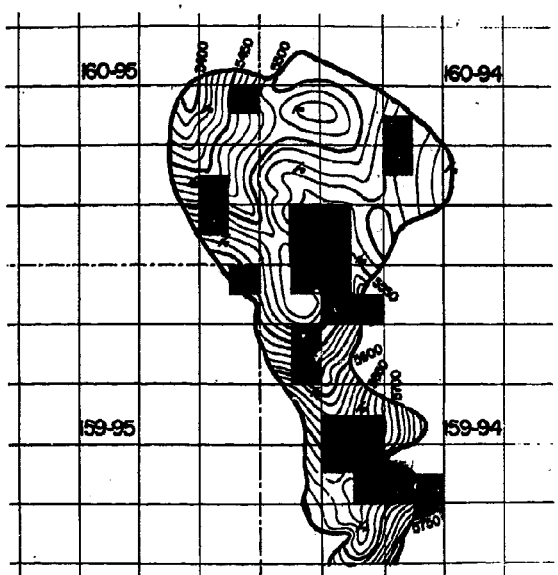


Fig. 5 NORTH TIOGA MADISON STRUCTURE ON MAIN PAY

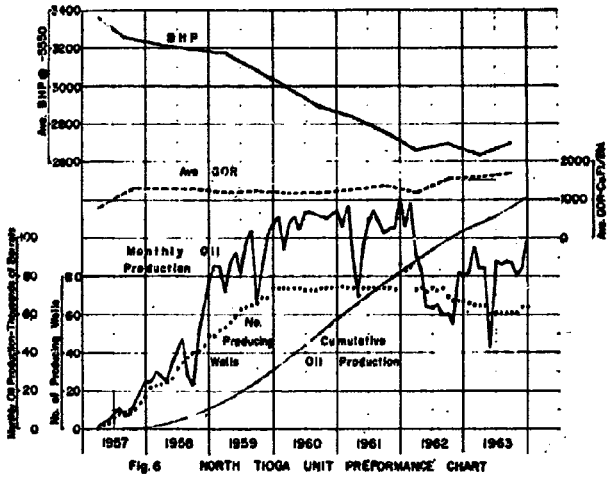


Fig. 6 NORTH TIOGA UNIT PREPORMANCE CHART