Independent
Oil & Gas Association
of New York

FINAL REPORT

IOGANY MARGINAL WELL STUDY

4335-ERTER-ER-96

This is the final report submitted to NYSERDA by IOGA of New York under the subject captioned project.

The project was developed due to the economic climate in New York State (low prices) which has resulted in a large number of wells being only marginally profitable. Most operators did not have the funds necessary to test these wells to determine whether these wells could be returned to a productive state. The study provided an inexpensive method for producers to submit wells with marginal production for an industry established suite of tests to possibly bring these shut in wells back to economic production.

The suite of tests was developed with industry participation. All testing was performed by Universal Well Services, the Sub Contractor in this project. Attached is the Aggregate Data Analysis of the project completed by the Sub Contractor. The results of the study were presented at a Seminar sponsored by NYSERDA and IOGANY.

After the completion of the testing, participants were mailed a questionnaire to determine the effectiveness of the marginal well study. Four of the fourteen participants completed and returned the questionnaire. Three of the four respondents performed work on the wells as a result of the tests performed. While several reported favorable results, there was not sufficient time to evaluate the effectiveness of the work performed at the time the questionnaire was completed. One operator felt that the price of gas did not warrant money to be spent on wells at the time of testing.

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AGGREGATE DATA ANALYSIS
IOGANY MARGINAL WELL STUDY

The IOGANY Marginal Well Study was completed in November of 1997. Fifty-five gas wells, located in seven New York State Counties, were tested in the study. The project was limited to natural gas wells. Fourteen operators participated in the study.

The Independent Oil and Gas Association of New York, Inc. was awarded funding for the Marginal Well Study by the New York State Energy Research and Development Authority. The objective of this project was to field test and evaluate marginal gas wells to determine their potential for additional gas production. Marginal gas wells included producing and shut-in wells that had not produced up to original expectations. The project was designed to provide operators with a relatively quick and simple method of cost-effective testing and evaluation. The operator fee was $200 per well. This low per well fee was possible due to NYSERDA co-funding of the project. IOGA of New York was the contractor of the project and Universal Well Services, Inc. was the subcontractor. Universal coordinated and conducted the well testing and evaluations.

Testing results were provided to participating operators. Operators received individual reports for each well tested. Each report included an interpretation of the test results. A sample copy of the report is attached. The scope of the project was limited to identifying wells with potential for additional production. No well rehabilitation was provided for under the scope of this project.

The following describes the testing, analysis and reporting performed by Universal Well Services, Inc. under the scope of this project and the results of the study:

I. Tests Conducted:

-Liquid Level Analysis
-Estimated Bottom Hole Pressure
-Slickline Service
-Production Water Analysis
-Wellhead Pressures

II. Testing Procedures:

Liquid Level Analysis- An echometer acoustic liquid level instrument was used to determine the liquid level in gas wells. This instrument sends a pressure pulse down the well and records the reflections received back at the surface. In wells with tubing, this pulse is induced in the tubing annulus with a sealed wellhead attachment which is connected to the casing at the surface. The induced pulse travels down the casing annulus and is reflected by tubing collars, obstructions and the liquid level. A microphone in the wellhead attachment converts the pressure pulse echoes into electrical signals which are amplified, filtered, and recorded on a strip chart. The liquid level is determined by counting the number of tubing collar reflections and therefore the number of tubing joints above the liquid reflection. The joint lengths are taken from the tubing tally and used to determine the liquid depth. For wells without tubing, liquid levels were calculated using an estimated acoustic velocity and one half the time for the pressure pulse to travel from the surface to the liquid level and back to the surface. The travel time is indicated on the strip chart. Acoustic velocity is controlled by temperature, pressure and gas specific gravity. Liquid levels were measured immediately when the wells were shut-in for testing so that the recorded level would indicate the level during production.

Bottom Hole Pressure- Static bottom hole pressure is the sum of wellhead casing pressure, gas column pressure, and liquid column pressure. Casing pressures were measured at the surface. The added downward force or back pressure exerted upon a formation by a column of liquid in the wellbore acts to inhibit the production of natural gas. The additional back pressure caused by a column of fluid can be calculated by the equation:

$$\Delta p = \rho g h$$

where Δp is the additional pressure, ρ is the density of the fluid, g is the acceleration due to gravity and h is the height of the fluid. This equation makes an assumption of uniform density throughout the fluid. It works well for wellbore liquids which are nearly incompressible and not greatly affected by temperature but does not work well for gases which are very compressible and temperature sensitive. To avoid this problem, a computer program was used to calculate bottom hole pressure using the Cullender and Smith method. This method uses iterative numerical techniques that account for variation in gas density due to increasing temperature and compression with depth. Bottom hole pressures were calculated to the middle of the perforated interval.

If a well has been in production, the estimated bottom hole pressure should represent a flowing bottom hole pressure. If a well has been shut-in and stabilized the estimated bottom hole pressure should represent the average reservoir pressure. Longer shut-in times are required for low permeability formations to stabilize than high permeability formations. The amount of shut in time necessary for a gas well to reach stabilization is proportional to the porosity, gas saturation, drainage area, permeability, and present average reservoir pressure. It can be calculated with the following equation:

$$t = \frac{1000(\phi S_g \mu_g r_e^2)}{k P_r}$$

where t is time, ϕ is porosity, S_g is gas saturation, μ_g is gas viscosity, r_e is radius of external no flow boundary, k is effective gas permeability, and P_r is average reservoir pressure.

Slickline Service- The slickline was used to determine the current total depth or tubing depth of wells. It was also used to obtain water samples from wells. A water sampling tool was lowered into wells on a truck mounted slickline. The tool is designed to retrieve a sample of production water from the deepest point it encounters in a well. A lubricator was attached to the wellhead to allow the slickline to be run into the well under pressure. The water samples obtained were used for water analysis. Some of the wells with tubing had seating nipples or mud anchors that prevented the slickline from being run below the tubing to measure the total depth. In these wells the slickline was used to determine tubing length.

Water Analysis- Water sampling and analysis were conducted in accordance with the American Petroleum Institute Recommended Practice for Analysis of Oil-Field Waters. Below are brief descriptions of the procedures used in this project.

pH- An electrometric method was used to measure pH. With this method, a meter with a pair of electrodes was used to determine hydrogen ion activity. The electrodes consist of a sealed glass half-cell which contains a solution of known pH and a reference half-cell. The two half-cells are submersed in the liquid sample to be tested. The meter measures the difference in electrical potential between the solution in the glass half-cell and the sample solution in contact with reference half-cell. The difference in potential varies with the pH of the sample solution. The variation in potential per pH unit is linear when temperature is constant.

Chlorides- Chloride concentrations were determined by the Mohr titration method. This method is based on the reaction between potassium chromate indicator and the first excess of standard silver nitrate titrant. Potassium chromate indicator is first added to the sample. Then silver nitrate titrant is slowly added to the water sample. The silver nitrate reacts with any chloride ions in the sample to form silver chloride. The end point is recorded when, after all the chloride has been consumed, the excess silver nitrate reacts with the potassium chromate indicator to form insoluble, brick red colored silver chromate. The amount of silver nitrate titrant is then used to calculate the chloride concentration.

Iron- Iron concentration was determined by titrating with a standard EDTA solution in the presence of salicylic acid indicator. When salicylic acid is added to a solution containing ferric iron at an acidic pH, a deep purple colored salicylic acid-ferric complex is formed. If necessary the pH of samples was adjusted to between 2 and 3 with sodium acetate buffer solution. In this pH range an EDTA-ferric iron complex is much stronger than a salicylic acid-ferric complex. Therefore, as EDTA is added there is a reduction in the purple salicylic acid complex. The end point is reached when the purple color disappears. The amount of EDTA is used to calculate the iron concentration. Water samples were "fixed" in the field by adding nitric acid to the samples. This insured that all dissolved iron was kept in solution until the sample was analyzed.

Specific Gravity- A hydrometer was used to determine the specific gravity of water samples. A hydrometer consists of a weighted bulb with a graduated stem. It is immersed in the water sample.

The depth to which the hydrometer sinks is controlled by the density of the liquid. The specific gravity is read directly from the graduated stem.

Wellhead Pressures- Casing and tubing pressures were measured at the wellhead with dead weight tested pressure gages. These pressures were recorded immediately before wells were shut-in for testing. Pipeline pressures were measured with a gage when possible or taken from the well chart.

III. Analysis of Test Results:

Liquid Level Analysis- High liquid levels are the cause of poor gas production in many gas wells. This is due to high bottom hole flowing pressures caused by the weight of the columns of liquid in these wells. This high back pressure inhibits the flow of gas into the wellbore. When excess liquid is identified, measures can be taken to lower the liquid level and reduce the bottom hole flowing pressure. A reduction in bottom hole flowing pressure can result in increased gas flow and allow wells to be returned to economical production.

Estimated Bottom Hole Pressure- Many wells are evaluated on the basis of pressures obtained at the wellhead. For wells that contain a column of liquid, these pressures may provide no indication of true bottom hole pressure. An estimated bottom hole pressure allows for a much more accurate evaluation of a wells production potential.

Production Water Analysis- Production water analysis allows for the identification of conditions which can cause poor production. Chloride concentration is used to indicate if produced water is connate water (production water) or water pumped into the well during stimulation or fresh water treatments. Low chloride concentration may also indicate an invasion of fresh water into the well due poor casing integrity. Iron concentrations can be used to predict the probability of formation damage due to iron oxide precipitation. High pH can also indicate the probability of metal oxide precipitation. Low pH may indicate that residual acid from stimulation or treatment is still present in the well which may accelerate corrosion. The specific gravity of water samples was used to calculate bottom hole pressures.

Slickline Service- A slickline (wireline) was used to indicate sand fill-up in wells or to verify the length (depth) of tubing in a well. Sand in the wellbore above the perforations can severely limit the production of a well. If this condition can be identified, measures can be taken to remove the sand and increase production. This may allow such wells to be returned to economic production. If the tubing is not set to the proper depth, it can limit the ability of the tubing to remove liquid from the well. The slickline was also used to find obstructions in tubing.

Wellhead Pressures- Casing pressure was used for the calculation of bottom hole pressure. Tubing pressure that is much less than casing pressure indicates an accumulation of liquid in the tubing which can limit production.

IV. Conditions Required for Testing

Because testing under this project required that equipment be attached to the wellhead, it was necessary for a company representative to be present during testing. Truck access to the wellhead was required for testing. Wells with casing plunger stands were not tested due to the inability to run the slickline past the stand.

V. Description of Wells Tested

Of the 55 wells tested 35 (64%) were located in Chautauqua County. The other wells were located in Allegany (3), Erie (4), Genesee (5), Livingston (4), Ontario (3) and Wyoming (1)Counties. The wells were completed in the following formations: Medina only (14), Whirlpool only (5), Medina and Whirlpool (30), Bass Island (3), Onondaga only (2), and Onondaga and Helderberg (1). When tested, 46 wells were producing and 9 were shut-in. Average daily production was reported in 31 of the producing wells. The production ranged from 0-40 MSCFD with an average of 9.2 MSCFD. Production of less than 20 MSCFD was reported in 90% of the wells tested. The total depth of the wells ranged from 1465 ft. to 4950 ft. with an average of 3161 ft. The total depths were as follows: 12 wells from 0-2000 ft. (22%), 9 wells from 2000-3000 ft. (16%), 19 wells from 3000-4000 ft. (35%) and 15 wells with depths greater than 4000 ft. (27%). Tubing was present in 35 wells (64%). Of these, 2 wells had 1 in. tubing, 30 wells had 1 ½ in. (86%) and 3 wells had 2 3/8 in. tubing. Plunger lift was present in 7 of the wells with tubing (20%).

VI. Results of Testing

Casing pressures were measured in all the wells tested. These pressures ranged from 0 to 775 psig. with an average of 150 psig. Casing pressures were less than 100 psig. in 25 wells (46%), 100-200 psig. in 15 wells (28%), 200-300 psig. in 9 wells (17%), 300-400 psig. in 3 wells (5%) and were greater than 400 psig. in 2 wells (4%). Tubing pressures in the 35 wells with tubing were from 0 to 368 psig. with an average of 93.5 psig. Tubing pressure was less than 100 psig. in 24 wells (69%), 100 to 200 psig. in 7 wells (20%) and more than 200 psig. in only 4 wells (4%). The pipeline pressures that the producing wells were flowing into ranged from 15 to 96 psig. with an average of 49.4 psig. Well pressure was the same as pipeline pressure in 17 of the producing wells (31%). These pressures were within 5 psi. in another 8 producing wells.

Liquid levels were measured in 53 wells. Liquid heights above the middle perforation ranged from 0 to 4154 ft. with an average height of 517 ft. If the heights of 0 are excluded, the average height increases to 703 ft. Liquid levels of 0 were recorded in 14 wells (26%), 0 to 100 ft. in 13 wells (24%), 100 to 500 ft. in 10 wells (19%), 500 to 1000 ft. in 4 wells (8%), 1000 to 2000 ft. in 9 wells (17%) and greater than 2000 ft. in 3 wells (6%).

Estimated bottom hole pressures were calculated for 53 wells. These pressures ranged from 21 to 2290 psia. with an average of 455 psia. Bottom hole pressures were less than 100 psia. in 2 wells (4%), 100 to 500 psia. in 35 wells (66%), 500 to 1000 psia. in 10 wells (19%), 1000 to 2000 psia. in 5 wells (9%) and 1 well had a bottom hole greater than 2000 psia.

Slickline testing indicated fill-up over perforations in 7 (20%) of the 35 wells in which the slickline could be run down to the current depth. It was not possible to run the slickline below the tubing in 20 wells due to seating nipples or mud anchors. Fill-up over perforations ranged from 1-73 ft. with an average of 28 ft. Of the wells with fill-up that were completed in both the Medina and Whirlpool formations, 5 had fill that completely covered the Whirlpool formation but did not extend up into the Medina. Tubing depth was measured in the wells in which the slickline could not be run below the tubing. Of these 22 wells, the actual tubing depth was found to be different from the recorded depth in 3 wells (14%).

Water samples were recovered from 48 wells. pH values ranged from 1.6 to 7.6 with an average pH of 4.2. Specific gravity values ranged from 1.00 to 1.225 with an average of 1.195. Chlorides ranged from 2,300 to 204,000 mg/l with an average of 176,000 mg/l. Iron ranged from 0 to 83,000 mg/l. Extremely high iron values of 83,000 and 69,250 mg/l were recorded in 2 wells. The average, without these high values, was 465 mg/l.

VII. Conclusions

The results of this study indicate that many of the test wells have the potential for additional production or, in the case of previously produced shut-in wells, the return to economic production. Conditions that may limit production were identified in 71% of the wells tested. In wells where no specific problems were identified, other valuable information was gained and potential problems were ruled out. For some wells, this testing was only a first measure and other more extensive testing would be necessary to fully evaluate their potential.

High liquid level was the most common problem affecting wells in the study. Liquid levels in excess of 100 ft. above the middle perforation were present in 49% of the 53 wells in which a liquid level was determined. If the liquid levels in these wells can be reduced and maintained at a low level, it may be possible to substantially increase the production potential of these wells. Liquids in gas wells can include water, condensate, or oil. Liquids can move into wells from the formation or condense out as gas rises and cools. Liquid accumulates in a well when the velocity of gas moving up the flow string is not sufficient to carry liquid to the surface. An accumulation of condensed water, which is fresh, can damage a formation that contains swelling clay.

Many methods can be used to remove liquid from wells and lower liquid levels. Tubing can be installed in casing wells to help lift liquid to the surface by reducing area and therefore increasing the velocity of gas flowing up a well. Smaller diameter tubing can be installed to further increase velocity and lift liquid in wells which already have tubing but do not effectively remove liquid. Wells can be produced intermittently so that when they produce they have higher pressures and therefore flow at higher velocities. Back pressure can be held against wells to help inhibit liquid flow from the formation into the wellbore. Soap can be introduced into wells to reduce the weight of liquids and make them easier to lift. Plunger lift systems (rabbits and casing plungers) can be used to lift liquids to the surface. Pumps, such as pump jacks, can be used to lift liquids to the surface. Swabbing of either casing or tubing with a service rig can also be used to remove liquid from wells. Swabbing is usually used to remove excessive amounts of liquid before initiating other measures to maintain a low liquid level.

It may be possible to increase the production of wells with fill-up over perforations by removing this fill. The fill in New York State gas wells usually consists of fracturing sand which has flowed back into the wellbore from the fracture. All of the Medina/Whirlpool wells tested in this study had been stimulated by hydraulic fracturing that used sand as the proppant to support the created fracture. Fill-up over perforations was not found in the other study wells which had not been hydraulically fractured. These other wells are completed in formations that are naturally fractured.

There is disagreement within the industry over the benefits of removing fracturing sand which has accumulated in the wellbore and covers perforations. Some operators report success and substantial improvements in production while others report that the sand removal resulted in no production increase. Two operators that reported success stated that a salt layer had formed on top of the sand fill and that it was necessary to break up this salt layer before the sand could be removed. This salt layer may form due to a pressure drop at the interface of the fill and the open wellbore. This layer could act as an impermeable plug and seal off the well below it.

Fill can be removed by using a sand pump or by circulating it out with tubing. To remove sand with tubing, nitrogen is pumped down the tubing annulus while lowering the tubing into the well. The flow of nitrogen up the tubing pulls the sand from the well.

Tubing was found to be set at a depth different then that recorded on the tubing tally in three of the 22 wells with tubing. Liquid can only be removed effectively to the depth of the bottom of the tubing. Therefore if tubing is set too high, liquid can accumulate in the area below tubing. If tubing is set too low, it will be below the level to which the liquid level can be drawn down. The tubing will fill with liquid until the weight of the liquid exceeds the pressure from below and the flow stops. Tubing should be set as low as possible to reduce the liquid level and associated back pressure as much as possible. The normal practice among operators in western New York State is to set the tubing just above the top perforation.

The water analyses indicated that 80% of the wells in which water samples were recovered contained normal formation water. Two wells had very high iron concentrations and also had low pH values. This indicates that, due to low pH, iron had been dissolved from either the wells tubulars or the formation. These two wells were both casing wells in which the water sampling tool was lowered to a depth below the perforations. It is likely that both water samples contained residual acid from stimulation that, since it was below the perforations, was never produced from the wells. Therefore, in both wells the iron content was probably due to corrosion of the casing in the area below the perforations. Five other samples had low pH values (<3.0) but were otherwise normal. The cause of the low pH readings in these wells is not known.

Two wells contained water with very low chlorides. Relatively fresh water from near the surface may have entered these wells. One well had casing set on a packer and was being produced at 5 psig. The other well had cemented casing with a casing pressure of 160 psig. Fresh water may have filled the casing annuluses of these wells and built up enough hydrostatic pressure to enter through a casing hole or around the packer.

Based on the test results and positive feedback from operators, it can be concluded that the goal of developing a simple cost-effective method of testing and evaluating marginal and shut-in gas wells was achieved by this study. No provisions were incorporated into this study to provide for the tracking of study wells. It is suggested that questionnaires be sent to participants to find out what measures were taken by operators as a result of the study and the success of those actions. A questionnaire could also be used to gather opinions and suggestions and to determine the overall satisfaction of the participants.

Cumulative Results

NUMBER OF WELLS:	55					
DATES TESTED:	12/6/96 TO 11/07/97					
COUNTIES(7):	ALLEGANY	3	GENESEE	5	WYOMING	1
	CHAUTAUQUA	35	LIVINGSTON	4		
	ERIE	4	ONTARIO	3		
FORMATIONS:	MEDINA ONLY	14	MEDINA & WHIRLPOOL	30	ONONDAGA ONLY	2
	WHIRLPOOL ONLY	5	BASS ISLAND	3	HELDERBERG AND ONONDAGA	1
PRODUCTION STATUS:	SHUT-IN	9	PRODUCING	46		
AVERAGE DAILY PRODUCTION (<20MSCFD IN 90% OF WELLS)	REPORTED	31	RANGE	0-40	MSCFD	
	NOT REPORTED	17	AVERAGE	9.2	MSCFD	
	NOT APPLICABLE	7				
DEPTH	RANGE	1465' - 4950'	0-2000'	12(22%)		
	AVERAGE	3161'	2000'-3000'	9(16%)		
			3000'-4000'	19(35%)		
			>4000'	15(27%)		
TUBING	PRESENT	35 (64%)	NOT PRESENT	20		
TUBING SIZE	1"	2	1 1/2"	30(86%)	2 3/8"	3
PLUNGER LIFT(TUBING WELLS)	PRESENT	7 (20%)	NOT PRESENT	28		
PIPELINE PRESSURE (12 N/A)	RANGE	15-96 PSI				
	AVERAGE	49.4 PSI				
CASING PRESSURE (1 N/A)	RANGE	0-775 PSI	<100 PSI	25(46%)		
	AVERAGE	149.9	100-200 PSI	15(28%)		
			200-300 PSI	9(17%)		
			300-400 PSI	3(5%)		
			>400 PSI	2(4%)		
TUBING PRESSURE (20 N/A)	RANGE	0-368 PSI	<100 PSI	24(69%)		
	AVERAGE	93.5 PSI	100-200 PSI	7(20%)		
			>200 PSI	4(11%)		
ESTIMATED BHP (2 N/A)	RANGE	21-2290 PSIA	<100 PSI	2(4%)		
	AVERAGE	454.9 PSIA	100-500 PSI	35(66%)		
			500-1000 PSI	10(19%)		
			1000-2000 PSI	5(9%)		
			>2000 PSI	1(2%)		
LIQUID HEIGHT (2 N/A) (ABOVE MID PERF)	RANGE	0-4154'	0'	14(26%)		
	AVERAGE (ALL)	517.2'	0-100'	13(24%)		
	AVERAGE (>0)	702.9'	100-500'	10(19%)		
			500'-1000'	4(8%)		
			1000'-2000'	9(17%)		
			>2000'	3(6%)		
FILL-UP OVER PERFS (20 N/A)	RANGE	1-73'	0' OR BELOW PERFS	28(80%)		
	AVERAGE	28'	ABOVE PERFS	7(20%)		
TUBING DEPTH (33 N/A)	CORRECT	19 (86%)				
	NOT CORRECT	3 (14%)				

WATER SAMPLES (7 N/A)

	RANGE	AVERAGE
pH	1.6-7.6	4.2
SPECIFIC GRAVITY	1.000-1.225	1.195
CHLORIDES	2,300-204,000	176,000
IRON	0-83,000	465 (w/o 83,000 & 69,250 samples)