Main Index

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CORIOLIS METER FOR LPG CUSTODY TRANSFER AT PETROBRAS

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SUMMARY
Testing was conducted at Petrobras to evaluate the suitability of a Coriolis meter to measure the mass of LPG in a custody transfer application. The test results demonstrate that the Coriolis meter is capable of accurate volume and density measurement, which verifies the capability of the Coriolis meter to accurately measure mass. When the Coriolis meter tests began, some mistakes were made in zeroing the meter. From the proving results, one can clearly see the impact of not properly performing the Coriolis meter's zero calibration, and the improvement in measurement accuracy once the meter is properly zeroed. Presently, the Coriolis meter shows less variation than the turbine meter and densitometer, which are being used to measure mass.

INTRODUCTION

The standard Petrobras LPG mass measurement system consists of turbine meters, vibrating tube densitometers, and flow computers for performing mass calculations and totalizing. Petrobras became interested in using Coriolis meters for custody transfer LPG measurement because they provide significant advantages over conventional mechanical meters: low maintenance, low cost, and multivariable measurement. The Coriolis meter is unique in that it provides both a direct mass flow measurement, and an independent density measurement, from which the volumetric flow rate can also be determined. Since there are no petroleum standards currently available for Coriolis meters, Petrobras initiated a test program to evaluate the suitability of a Coriolis meter for the custody transfer measurement of LPG.

TEST SETUP AND PROCEDURES

The primary objective of the testing was to evaluate the ability of a Micro Motion model CMF300 Coriolis meter to measure the mass of LPG in a custody transfer application. A Brook's Compact Prover was used to evaluate meter flow measurement accuracy. This prover measures volume, and was not instrumented with a densitometer to determine the mass of the fluid measured by the prover. Since equipment was not available for mass proving, Petrobras decided to field prove the Coriolis meter's volume and density measurements. If the volume and density measurements are acceptable, the mass must also be acceptable, because the Coriolis meter volume is derived from the mass and density measurements. Because a Compact Prover was used, the Coriolis meter could not be tested at the normal delivery flow rate of ≈300 m^3/hr. Due to response time constraints, the Coriolis meter requires at least a 0.67 second prerun time prior to beginning to accumulate flow pulses. In order to meet this prerun requirement the Coriolis meter proving flow rate was limited to 210 m^3/hr or less. Inventory comparisons between the turbine meter and Coriolis meter were performed to determine if a meter factor obtained for the Coriolis meter at an average flow rate of 170 m^3/hr would be valid at higher flow rates.

A secondary objective was to compare the performance of the Micro Motion CMF300 Coriolis meter to the existing measurement devices, the 6" Smith turbine meter, and the Dynatrol densitometer. A schematic of the field test facility employed at Petrobras' REPLAN refinery is shown in Figure 1.

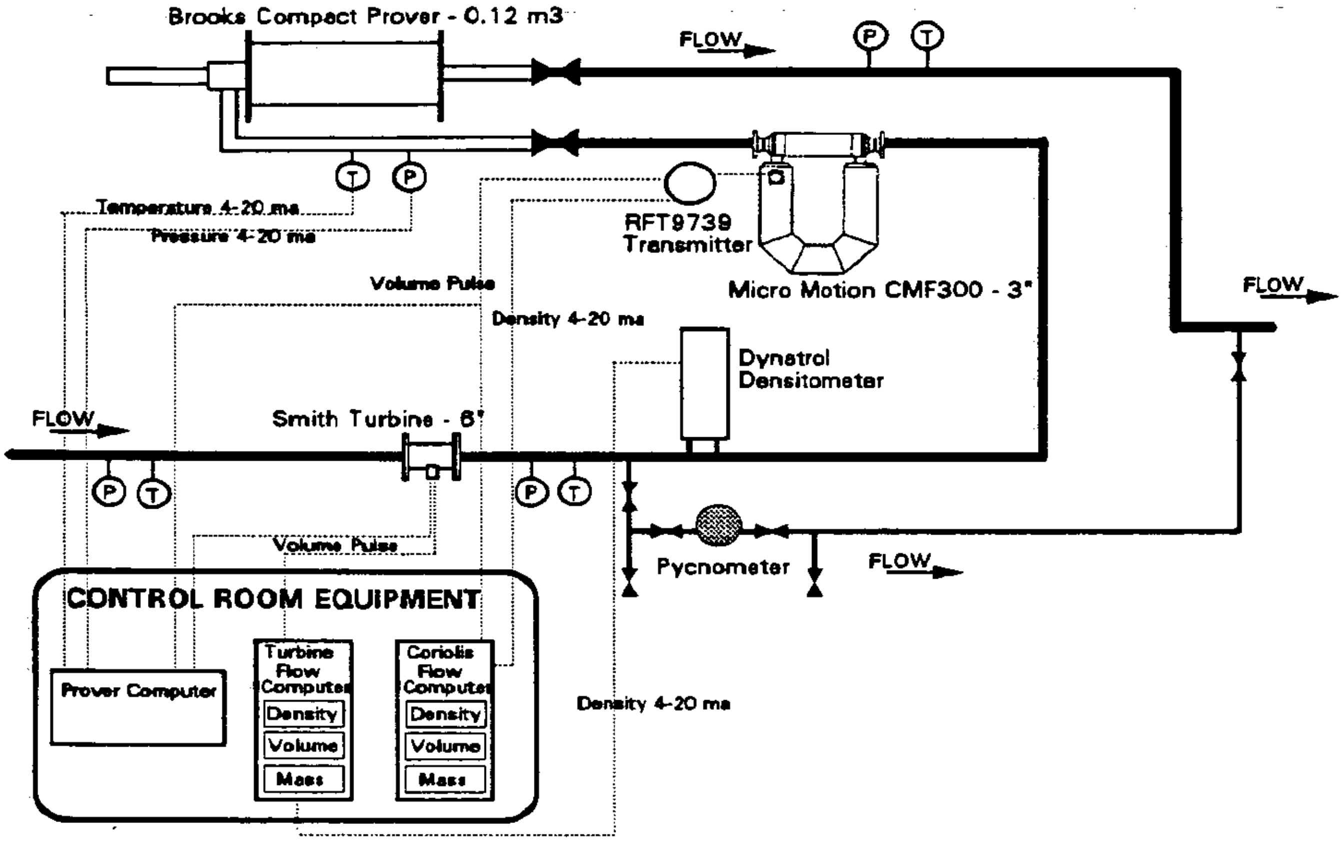

Figure 1. Petrobras REPLAN field measurement test facility

The volumetric flow measurement of the turbine and the Coriolis meter were proved against the 0.12 m^3 Brooks Compact Prover. Proving sessions were typically performed at least once per month for one year. For the turbine meter each proving consisted of 5 runs of 4 passes each. For the Coriolis meter 3 runs of 12 passes each were used. The meter factor was calculated by dividing the prover volume by the meter's measured volume. On average, 4-5 provings were performed for each proving session. The flow rate was usually varied between provings to evaluate the linearity of the meters. The prover computer would only accept one meter input, so the meters were not proved simultaneously.

The Dynatrol and the Coriolis meter's density measurements were proved with a pycnometer. The pycnometer is a pressure vessel of known volume and evacuated weight. Density is determined by weighing the filled vessel, and calculating density by dividing the mass of the product by the known volume. The pycnometer system was located at the Dynatrol. The procedure that was employed was to take the pycnometer sample and obtain the density measurements from the flow computers via radio transmission from the control room. The density indications from both the Dynatrol and the Coriolis meter were recorded simultaneously. The density factor is equal to the pycnometer density divided by the meter's density reading. The limitation with this method is that the Coriolis meter is located approximately 12 meters from the pycnometer, and the conditions at the meter will generally be slightly different than at the pycnometer - resulting in somewhat different densities at these two locations. The density difference between the pycnometer and the Coriolis meter does not remain constant because the pressure drop between the two locations changes with changing flow rate. The density of LPG is significantly affected by the operating pressure. The effect of pressure differences was not studied.

The inventory comparisons between the turbine and the Coriolis meter were very straightforward. After normal product deliveries to customers, the volume totals from the turbine and Coriolis meter were obtained from their respective flow computers. The Coriolis meter totals were compared to the turbine meter totals.

TEST RESULTS AND DISCUSSION

Volume Meter Factors

Table 1 shows the results of the volumetric provings from June 1995 to January 1996.

Table 1. Volume meter factor summary - June 1995 to January 1996

DATE	CORIOLIS METER AVERAGE METER FACTOR	CORIOLIS METER AVERAGE REPEAT. (%)	CORIOLIS METER METER FACTOR VARIATION (%)	TURBINE METER AVERAGE METER FACTOR	TURBINE METER AVERAGE REPEAT. (%)	TURBINE METER METER FACTOR VARIATION (%)
29-Jun-95	1.0112	0.018	0.186	0.9279	0.033	0.112
12-Jul-95	1.0122	0.020	0.210	0.9281	0.026	0.049
27-Jul-95	1.0121	0.035	0.254	0.9290	0.030	0.169
9-Aug-95	1.0110	0.031	0.157	0.9276	0.022	0.117
13-Sep-95	1.0111	0.039	0.279	0.9283	0.035	0.199
28-Sep-95	1.0112	0.031	0.167	0.9297	0.021	0.176
10-Oct-95	1.0123	0.032	0.527	0.9285	0.044	0.061
8-Dec-95	1.0107	0.036	0.064	0.9292	0.031	0.103
5-Jan-96	1.0140	0.031	0.129	0.9294	0.040	0.166
AVERAGE	1.0118	0.030	0.219	0.9286	0.031	0.128

As was stated previously, an average of 4-5 provings were performed each proving session. The first column of data presents the average meter factor obtained from these proving sessions. The second column of data is the average of the repeatabilities obtained for each proving. The criteria for acceptable repeatability is the meter factor variation between proving runs must be less than 0.05%. It can be seen that both the Coriolis meter (0.030%) and the turbine meter (0.031%) meet the repeatability criteria. The third column shows the variation between the maximum and minimum meter factors from each proving session. The Petrobras criteria is that the meter factor variation between provings must be less than ±0.15%. The variation between the average meter factors for the Coriolis meter fell within acceptable tolerances, except for January 5. However, the Coriolis meter showed excessive meter factor variation between the provings performed each session. Also, the average meter factor for the Coriolis meter (1.0118) indicated that it was reading low by approximately 1.2%. The meter factor should be much closer to 1.0000, for there to be agreement with the meter's factory calibration. It was felt that the Coriolis meter should perform better.

Upon consulting with Micro Motion, it was suggested that the Coriolis meter had not been properly zeroed. In order to validate this hypothesis, the meter factors for the Coriolis meter were plotted against flow rate, as shown in Figure 2.

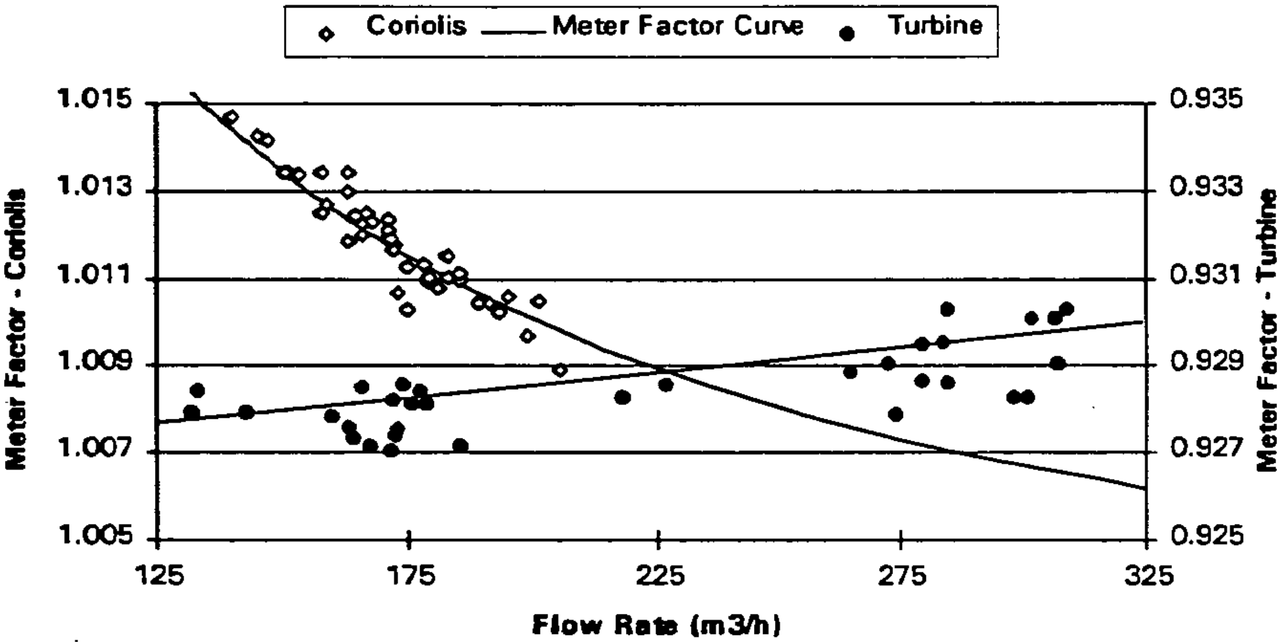

Figure 2. Coriolis and turbine meter factors versus flow rate (prior to rezeroing the Coriolis meter)

The data shows the characteristic trend of an improperly zeroed Coriolis meter. Probable causes of the improper zeroing of the Coriolis meter are: the meter was zeroed with a small amount of flow going through meter, or the meter was not zeroed when a new transmitter was installed. Micro Motion does not recommended routine meter rezeroing. However, they advise occasional checking of the meter zero. Equation 1 is used to determine if the meter needs to be rezeroed.

$$\text{Flow Measurement Error } (\%) = \frac{\text{Flow rate indication with no flow}}{\text{Normal operating flow rate}} * 100 \qquad (1)$$

Flow is halted, then the meter's flow rate indication with no flow is recorded. Equation 1 is used to calculate the resulting error. If the error exceeds acceptable tolerances, the meter should be rezeroed.

The Coriolis meter was rezeroed on January 15, 1996. Figure 3 shows that rezeroing dramatically improved the linearity of the meter. In addition, rezeroing resulted in an average meter factor for the Coriolis meter of 0.9991. Therefore, the difference between the prover and the meter's factory calibration is only 0.09%.

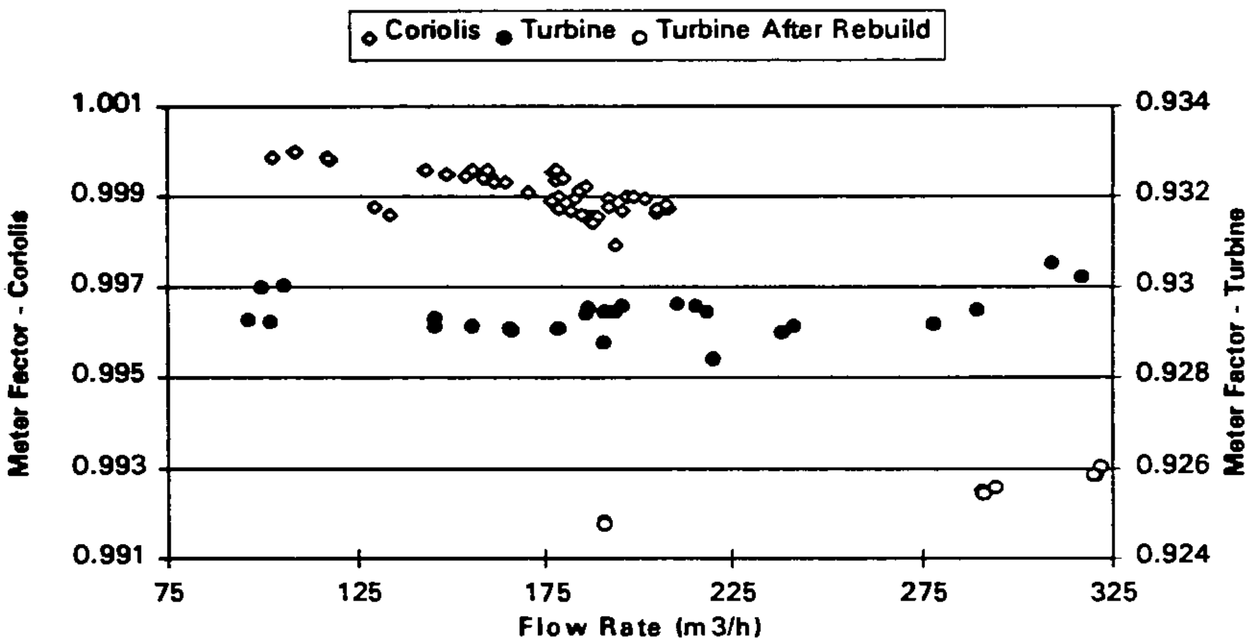

Figure 3. Coriolis and turbine meter factors versus flow rate (after rezeroing the Coriolis meter)

Table 2 presents the meter factor summary from January 1996 to May 1996. This table shows several interesting points. First, the average proving repeatabilities for both the turbine (0.036%) and the Coriolis meter (0.032%) are well within the 0.05% requirement. Second, the meter factor variation between provings improved tremendously for the Coriolis meter (average of 0.043%). Finally, a hole developed in the strainer upstream of the turbine meter, and some "dirty" LPG damaged the turbine meter. The turbine meter was rebuilt on May 14, 1996. The Coriolis meter was unaffected by exposure to the "dirty" LPG. In summary, once the Coriolis meter was zeroed properly its performance was excellent.

Table 2. Meter factor summary - January 1996 to June 1996

	CORIOLIS METER			TURBINE METER		
DATE	AVERAGE METER FACTOR	AVERAGE REPEAT. (%)	METER FACTOR VARIATION (%)	AVERAGE METER FACTOR	AVERAGE REPEAT. (%)	METER FACTOR VARIATION (%)
19-Jan-96	0.9988	0.026	0.054	No provings for turbine		
24-Jan-96	0.9988	0.034	0.046	0.9296	0.043	0.079
9-Feb-96	0.9991	0.026	0.031	0.9290	0.026	0.037
23-Feb-96	0.9999	0.013	0.019	0.9296	0.061	0.082
8-Mar-96	0.9988	0.056	0.055	0.9294	0.033	0.145
27-Mar-96	0.9985	0.032	0.107	0.9293	0.030	0.121
28-Mar-96	0.9986	0.044	0.038	0.9293	0.032	0.031
16-Apr-96	0.9995	0.029	0.008	0.9292	0.021	0.016
21-May-96	0.9995	0.021	0.028	0.9273[a]	0.027	0.119
22-May-96	0.9995	0.030	0.019	0.9263[a]	0.028	0.163
29-May-96	0.9988	0.044	0.029	0.9255[b]	0.024	0.122
AVERAGE	0.9991	0.032	0.043	0.9293[c]	0.035[c]	0.073[c]

(a) Turbine bearings replaced and rotor cleaned May 14, 1996. One pick-up was still bad.
(b) Turbine pickup repaired May 23, 1996.
(c) Averages do not include values after turbine was repaired on May 14, 1996.

Density Factors

The density factors for the Dynatrol and the Coriolis meter are presented in Figure 4. While there was some scatter in the density factors for the Coriolis meter, the overall average was 1.00002, which is outstanding.

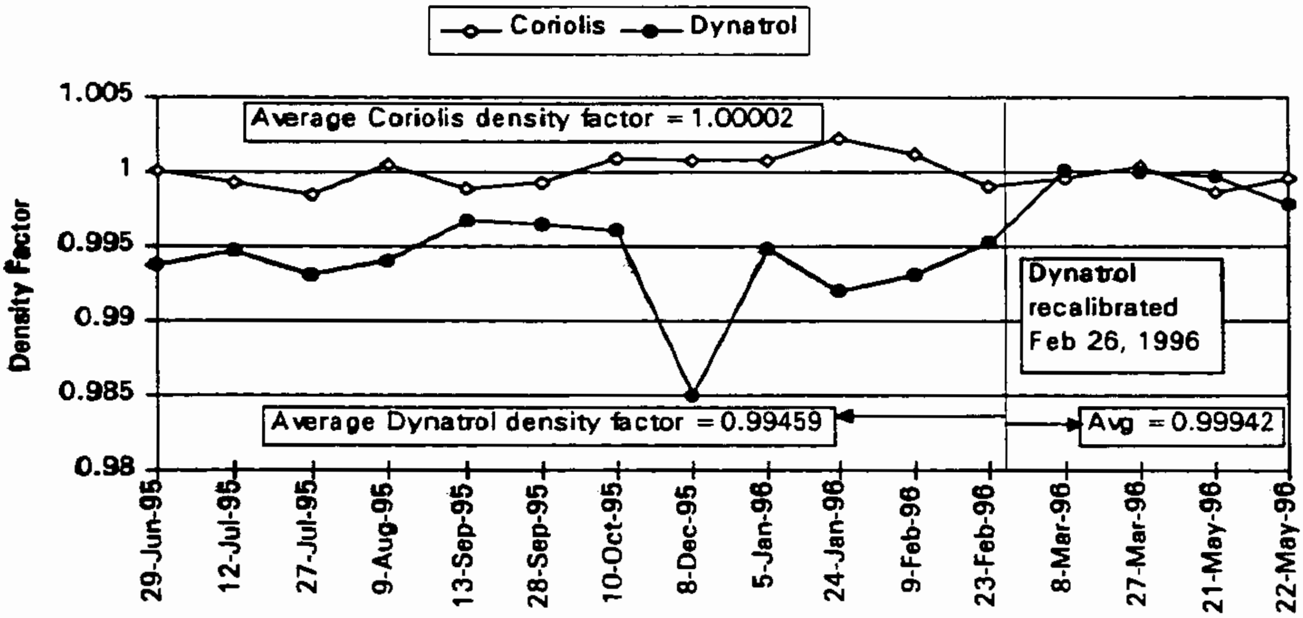

Figure 4. Density factors for Coriolis and Dynatrol density measurements

The scatter in the density factors for the Dynatrol were very similar to the Coriolis meter, except for an extreme point on Dec. 8, 1996. The repeatabilities for the density provings were fairly poor, the average repeatability for the Coriolis meter was 0.141%, and for the Dynatrol was 0.212%. The pycnometer proving procedure may not have been rigorous enough. In general, the density proving demonstrates the Coriolis meter's density measurement is very accurate and reliable.

Inventory Comparison

The gross volume inventory comparisons between the turbine and Coriolis meter are shown in Figure 5.

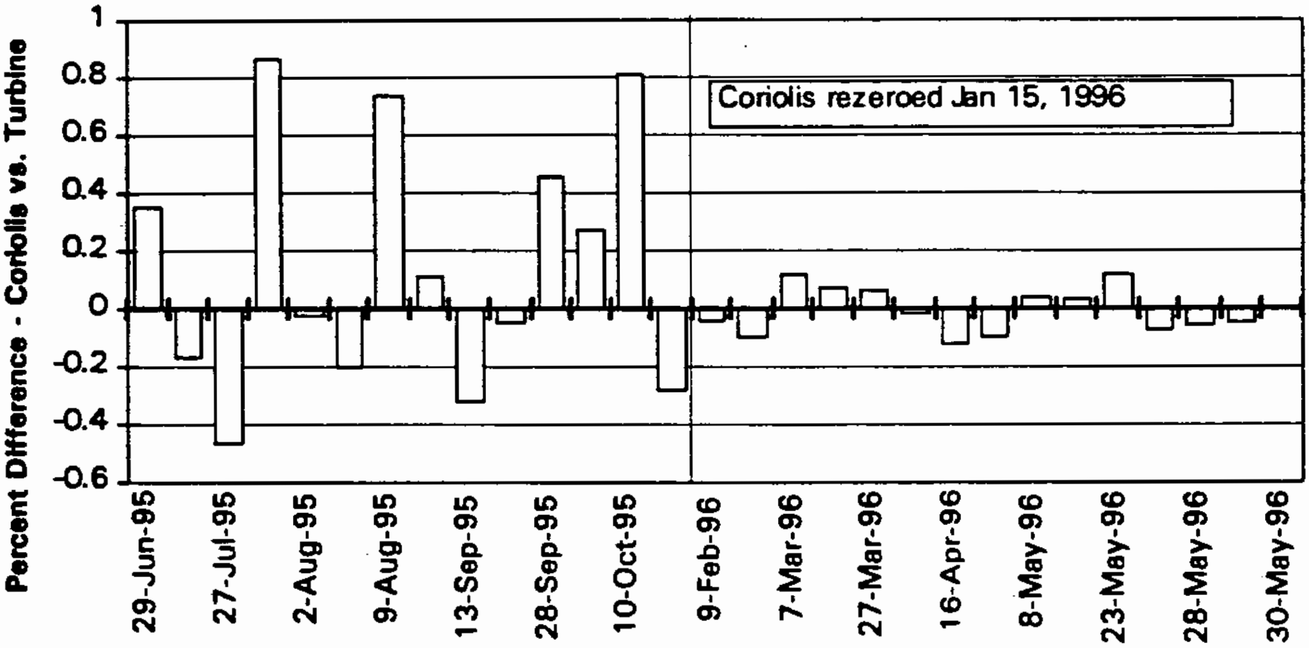

Figure 5. Inventory comparison between Coriolis and turbine meter measured volumes

The data prior to rezeroing the Coriolis meter is very disappointing. Six of the fourteen comparisons are outside of the Petrobras specification of 0.3% agreement between meters. These results are consistent with a zero offset in the Coriolis meter. The meter factor for the Coriolis meter that was programmed into the flow computer was 1.0117, based on an average flow rate of 170 m^3/h. However, the inventory comparisons were done at a variety of flow rates, up to 300 m^3/hr. Since the Coriolis meter was not properly zeroed, the meter factor determined at 170 m3/hr would not be applicable at other flow rates. For the remaining fifteen inventory comparisons after the meter was rezeroed, the greatest variation was 0.12%. These results demonstrate that if the Coriolis meter is properly zeroed, it can be proved at a low flow rate and be used to measure product at a higher flow rate.

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