THE AGA TRANSMISSION MEASUREMENT COMMITTEE AND THE REVISION OF AGA REPORT No 8 COMPRESSIBILITY FACTORS OF NATURAL GAS

by

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Paper 4.2

NORTH SEA FLOW MEASUREMENT WORKSHOP
26-29 October 1992

NEL, East Kilbride, Glasgow

The A.G.A. Transmission Measurement Committee and the Revision of A.G.A. Report No. 8 on Compressibility Factors of Natural Gas

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SUMMARY

In the United States and Canada, there are several organizations that are directly involved in improving the understanding and practice of natural gas measurement. One of these organizations, the A.G.A. Transmission Measurement Committee, is described in this paper. This paper also discusses the results of a recently completed project of that committee, the 1992 revision to A.G.A. Report No. 8 on Compressibility Factors of Natural Gas. As part of this discussion, two new compressibility calculation methods will be compared to each other and to the NX-19 method for a reference Ekofisk Gas as well as two gas compositions found in the North Sea.

1. FLOW MEASUREMENT ORGANIZATIONS IN THE U.S.

The following is a list of the major U.S. organizations directly involved with the research, testing, technical recommendations, standards, and regulatory matters of natural gas measurement.

A.G.A. / TMC / DMC	American Gas Association / Transmission Measurement Committee / Distribution Measurement Committee
API / COPM / COGM	American Petroleum Institute / Committee on Petroleum Measurement / Committee on Gas Measurement
ASME / MFC	American Society of Mechanical Engineers / Committee on Measurement of Fluid Flow in Closed Conduits
ASTM	American Society for Testing and Materials
GPA	Gas Processors Association
GRI	Gas Research Institute

2. THE AMERICAN GAS ASSOCIATION

The American Gas Association (A.G.A.) is a national trade association with a membership from 250 natural gas distribution and transmission companies located throughout the United States and Canada, as well as overseas.

The A.G.A. staff consists of approximately 180 people located in Arlington, Virginia, just across the Potomac River from Washington, D.C. Another 180 people work in the A.G.A. Laboratories, Cleveland, Ohio, testing and certifying gas appliances. A.G.A.'s annual budget is approximately $50 million, supported by member dues, testing fees, conference registrations, publication sales and other sources.

The A.G.A. committees are organized into four sections:

1. Legal Section
2. Marketing Section
3. Financial and Administrative Section
4. Operating and Engineering Section

Each section has several committees made up of member company experts. These committees typically meet two or three times a year to discuss mutual problems, share solutions, produce recommended practices and/or standards, and formulate gas industry policies. A.G.A.'s government relations and communications staff then strive to effectively communicate these policies, etc. to legislators, regulators, and industry. For example, A.G.A. spends about $15 million per year on national advertising, describing the benefits and advantages of natural gas to our customers.

The A.G.A. Operating and Engineering Section consists of about 700 technical experts representing their individual companies, on 17 different committees.

Committee	Members
Automation and Control	38
Compressor	28
Corrosion Control	29
Customer Service and Utilization	40
Distribution, Construction and Maintenance	63
Distribution Engineering	40
Distribution Measurement	35
Environmental Matters	46
Fleet Management	44
Gas Control	35
Materials Management	30
Pipeline	31
Plastic Materials	68
Safety and Occupational Health	37
Supplemental Gas	37
Transmission Measurement	49
Underground Storage	40
TOTAL =	**690**

Committee activities and projects are aimed at addressing a set of key industry issues: saftey, regulations/standards, environmental, communication, Gas Engineering and Operating Practices Series of books, technology, third party damage, quality and productivity improvement, and research identification.

3. THE A.G.A. TRANSMISSION MEASUREMENT COMMITTEE (TMC)

The TMC consists of 20 members from transmission and distribution companies, and 26 associated members from manufacturing, research, and educational institutions.

The scope of projects covered by the TMC include the procedures and practices for installing, operating, testing and maintaining metering and associated equipment, including volume and pressure control equipment which is used in the production, gathering and transmission of natural and substitute gas from the source to the outlet of a transmission line gate station. Also included in the scope of TMC activities are the scientific principles, applications and usage of all types of volumetric, weight, and energy measurement devices associated with the metering equipment specified above.

The current three year plan for the TMC includes the following projects:

1. Revise A.G.A. Report No. 8 on the Compressibility Factors of Natural Gas.
2. Revise A.G.A. Report No. 7 on the Measurment of Gas by Turbine Meters.
3. Revise A.G.A. Report No. 4A on Natural Gas Contract Measurement and Quality Clauses.
4. Develop a small Field Guide for the new revision of A.G.A. Report No. 3 on Orifice Metering.
5. Continue to provide direction to the research community to ensure results have value to members.
6. Provide tehcnical support to other organizations revising measurement standards, e.g. API, GPA, etc.

4. THE REVISION OF A.G.A. REPORT NO. 8

As an example of a recent TMC project, the remainder of this paper will describe a major project just completed, the revision of A.G.A. Report No. 8, Compressibility Factors of Natural Gas and Other Related Hydrocarbon Gases. This report is in the final stages of review and will be available to users in the gas industry in December 1992. This report is based on a large amount of supporting research conducted in North America under the sponsorship of the Gas Research Institute and in Europe under the sponsorship of the Groupe Europeen de Recherches Gazieres (GERG), Gasunie, Ruhrgas, Gaz de France, and British Gas. The report will be accompanied by a diskette of FORTRAN subprograms as well as a utility program for calculating compression factors based on a variety of inputs.

4.1 Background

During the period 1981-1984, the A.G.A. through its Transmission Measurement Committee and the GRI sponsored development of an equation of state to provide the gas industry with state-of-the-art predictions of compressibility factors for natural gas metering applications. Initial work used data ranging in pressure up to approximately 6 MPa obtained from the literature and provided by the GERG. However the GERG data bank was extended considerably in the period 1985-1990. The new data showed that the original equation developed in the period 1981-1984 needed improvement. In addition, velocity of sound data obtained under GRI sponsorship during 1985-1989 showed calculations for rich gases were not sufficiently accurate for critical flow applications. These data were included in a new thermodynamic property correlation for natural gas mixtures. The resulting equation of state is referred to as the Detail Characterization Method and is documented in A.G.A. Report No. 8.

4.2 Natural Gas Characterization Methods

Two highly accurate models for computing compressibility factors in gas measurement applications are presented in A.G.A. Report No. 8. One model applies a detailed knowledge of natural gas composition to compute the compressibility factor (i.e. using standard composition information from a chromatographic analysis). This is the Detail Characterization Method and can be applied over a wide temperature, pressure, and composition regime. A second model applies an aggregate or gross knowledge of natural gas composition to compute the compressibility factor. This model is the Gross Characterization Method which was developed under sponsorship from the Groupe Europeen de Recherches Gazieres (GERG). The method can be applied within the custody transfer region which extends from 265 to 335 K at pressures less than 12 MPa. Neither model is recommended in the liquid phase or within 5K and 0.2 MPa of the critical point.

The Gross Characterization Method was developed by GERG and modified for implementation in the U.S. These modifications have to do with the specification of reference conditions for metering and for determination of heating value. The Detail Characterization Method was developed using a three step procedure using compressibility factor data obtained from the literature and provided by GERG.

(1) First, an equation of state for key pure components was developed using compressibility factor data for methane, ethane, nitrogen, hydrogen, and carbon dioxide along with velocity of sound data for methane. The equation of state terms were chosen using a procedure which minimizes the number of terms required for a given accuracy.

(2) Second, compressibility factor data for key binary mixtures were used to determine binary interaction parameters for key binary component pairs.

(3) Third, the GERG compressibility factor data for 84 natural gas mixtures were used to evaluate the accuracy of the equation of state for natural gas compressibility factors. In addition, velocity of sound data measured by NIST for four natural gas mixtures were used to evaluate the equation of state for velocity of sound predictions.

The Detail Characterization Method and the Gross Characterization Method have been incorporated into efficient computer programs for computing the compressibility factor, Z, the mass density, ρ, and the supercompressibility factor, Fpv. The programs have been designed for the following purposes: (1) efficient implementation on flow computers, (2) as a guide for the development of application programs in the gas industry, (3) for computational verification; and (4) for utility purposes such as tabulating Z, ρ, or Fpv for particular gas mixture compositions.

4.3 Reference Data for Natural Gas Mixtures

During the last two years the Gas Research Institute in coordination with Gasunie, Ruhrgas, and Gaz de France have sponsored highly accurate measurements of natural gas mixtures at the National Institue for Standards and Technology (NIST), Texas A&M, Van der Waals Laboratory, and Ruhrgas. PVT data for the five natural gas mixtures shown in Figure 1 were obtained in this research. All mixtures were gravimetrically prepared and chromatographically verified by NIST and then sent to each of the participating laboratories. Density measurements were taken over temperatures from 225 to 350K and at pressures up to 70 MPa. These "reference data" represent the state-of-the-art in PVT measurements for natural gas mixtures. Intercomparison of the data shows an average agreement between the experimental measurements from the four laboratories of 0.035%. These PVT reference data were acquired after finalization of the Detail Characterization Method and the Gross Characterization Method. As such, these data provide an independent verification of both characterization methods.

Figure 2 compares PVT reference data for Ekofisk gas with density predictions from the Detail Characterization Method as well as the Gross Characterization Method at 275K and 300K. Density deviations are calculated as,

$$(\rho_{data} - \rho_{calc}) / \rho_{data} * 100. \qquad (1)$$

Figure 3 compares density predictions from the Gross Characterization Method against those from the Detail Characterization Method for Ekofisk Gas. Density deviations are calculated as,

$$(\rho_{gross} - \rho_{detail}) / \rho_{detail} * 100. \qquad (2)$$

Despite the agreement in predicted densities, these methods give significantly different derived properties such as velocity of sound and heat capacity. Figure 4 compares density predictions from the NX-19 Method against the Detail Characterization Method for Ekofisk Gas. Density deviations are calculated as,

$$(\rho_{NX\text{-}19} - \rho_{detail}) / \rho_{detail} * 100. \qquad (3)$$

Both the Detail and Gross Characterization Methods represent the density Ekofisk Gas within 0.05% at pressures less than 12 MPa, while the NX-19 Method is in error as much as 2%. As the concentration of heavier hydrocarbons increases, the differences in predicted density between all three methods becomes more pronounced. Molar composition of natural gas from two North Sea fields is given in Figure 5. Figure 6 compares density predictions from the Gross Characterization Method against the Detail Characterization Method for the Statfjord Gas. Figure 7 compares density predictions from the NX-19 Method against the Detail Characterization Method for Statfjord Gas. Figure 8 compares density predictions from the Gross Characterization Method against the Detail Characterization Method for Veslefrikk Gas. And Figure 9 compares density predictions from the

NX-19 Method against the Detail Characterization Method for Veslefrikk Gas. Figures 6-9 illustrate that the Detail Characterization Model should be favored in predicting compressibility factors for rich gas mixtures such as those found in the North Sea. Unfortunately, little reference quality experimental data are available for evaluating the accuracy of compressibility factor predictions for rich gas mixtures.

4.4 Recommendation to Gas Industry Users

In the United States the Gross Characterization Method will be implemented primarily for transmission/distribution system applications. This method will only be used for compressibility factor calculations. All derived physical properties will be calculated with the Detail Characterization Method. The Detail Characterization Method is applicable to transmission/distribution conditions and is expected to be applicable to a broad range of production/processing conditions. Research is underway to investigate the data and modeling needs for heavier gas constituents.

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JAESCHKE, M., Ruhrgas A.G., and HUMPHREYS, A.E., British Gas plc.,GERG Technical Monograph 5, 1991.

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		GULF (NIST1)	AMARILLO (NIST2)	EKOFISK (RG2)	High N_2 (GU1)	High CO_2 (GU2)
CH_4	Methane	96.6	90.7	85.9	81.3	81.2
N_2	Nitrogen	0.3	3.1	1.0	13.6	5.7
CO_2	Carbon Dioxide	0.6	0.5	1.5	1.0	7.6
C_2H_6	Ethane	1.8	4.5	8.5	3.3	4.3
C_3H_8	Propane	0.4	0.8	2.3	0.6	0.9
C_4H_{10}	Butane	0.2	0.3	0.7	0.2	0.3
C_5H_{12}	Pentane	0.1	0.1	0.1	-	-

Figure 1. Percent molar composition of PVT Reference data for Natural Gas Mixtures.

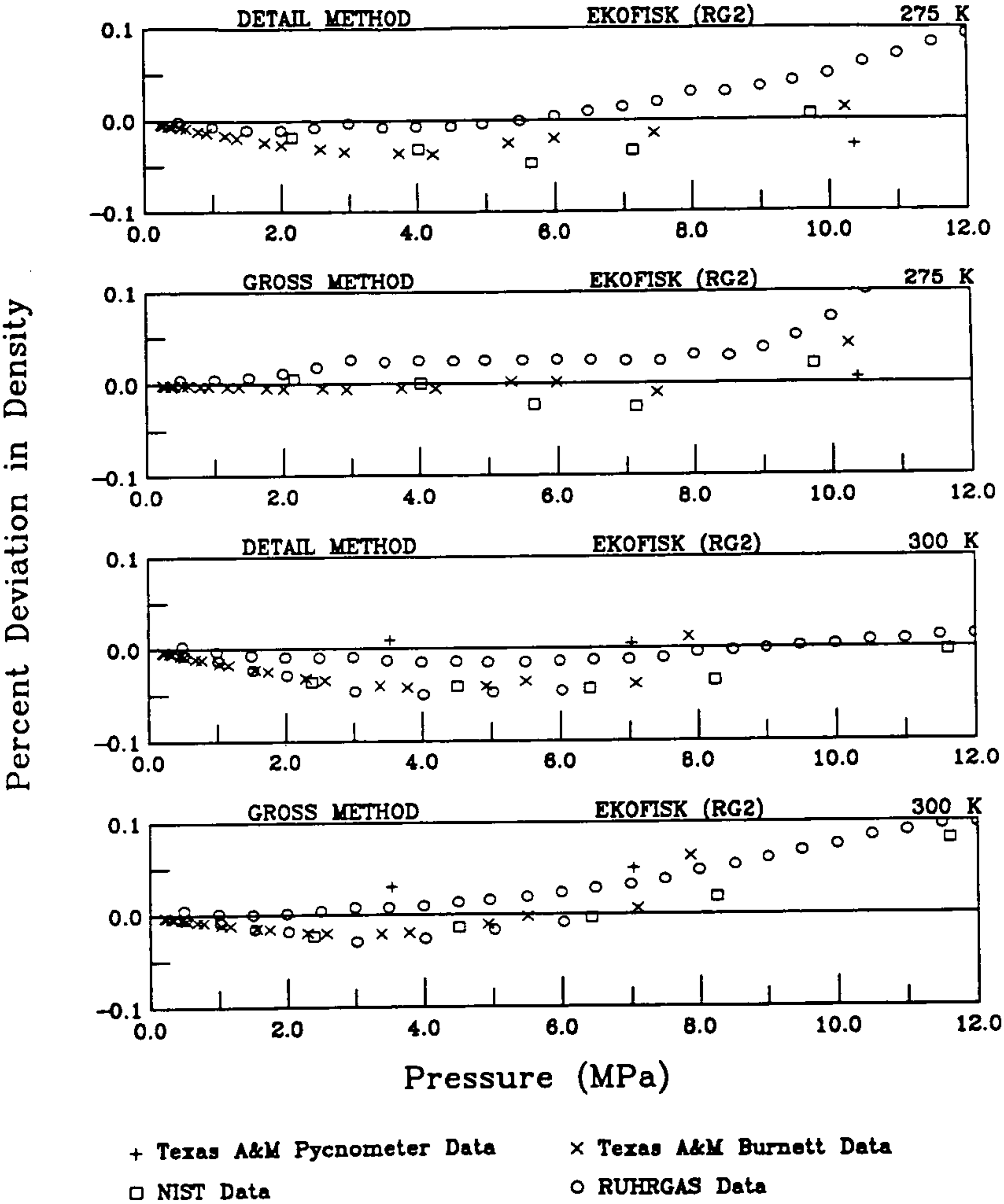

Figure 2. Percent Deviation between Experimental PVT Data and Densities Predicted from the Detail Characterization Method and the Gross Characterization Method.

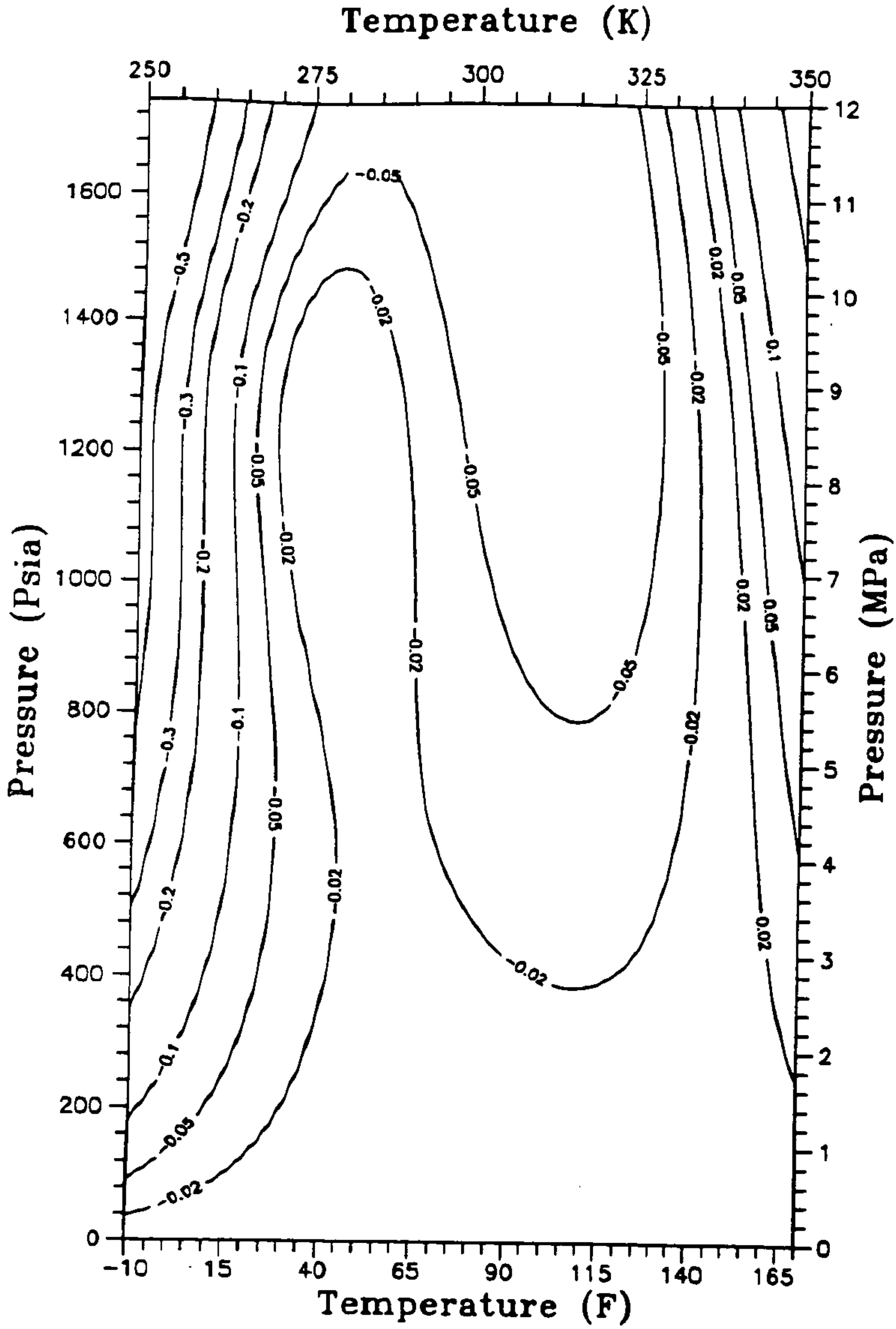

Figure 3. Deviation in Predicted Density between the Gross Characterization Method and the Detail Characterization Method for Ekofisk Gas.

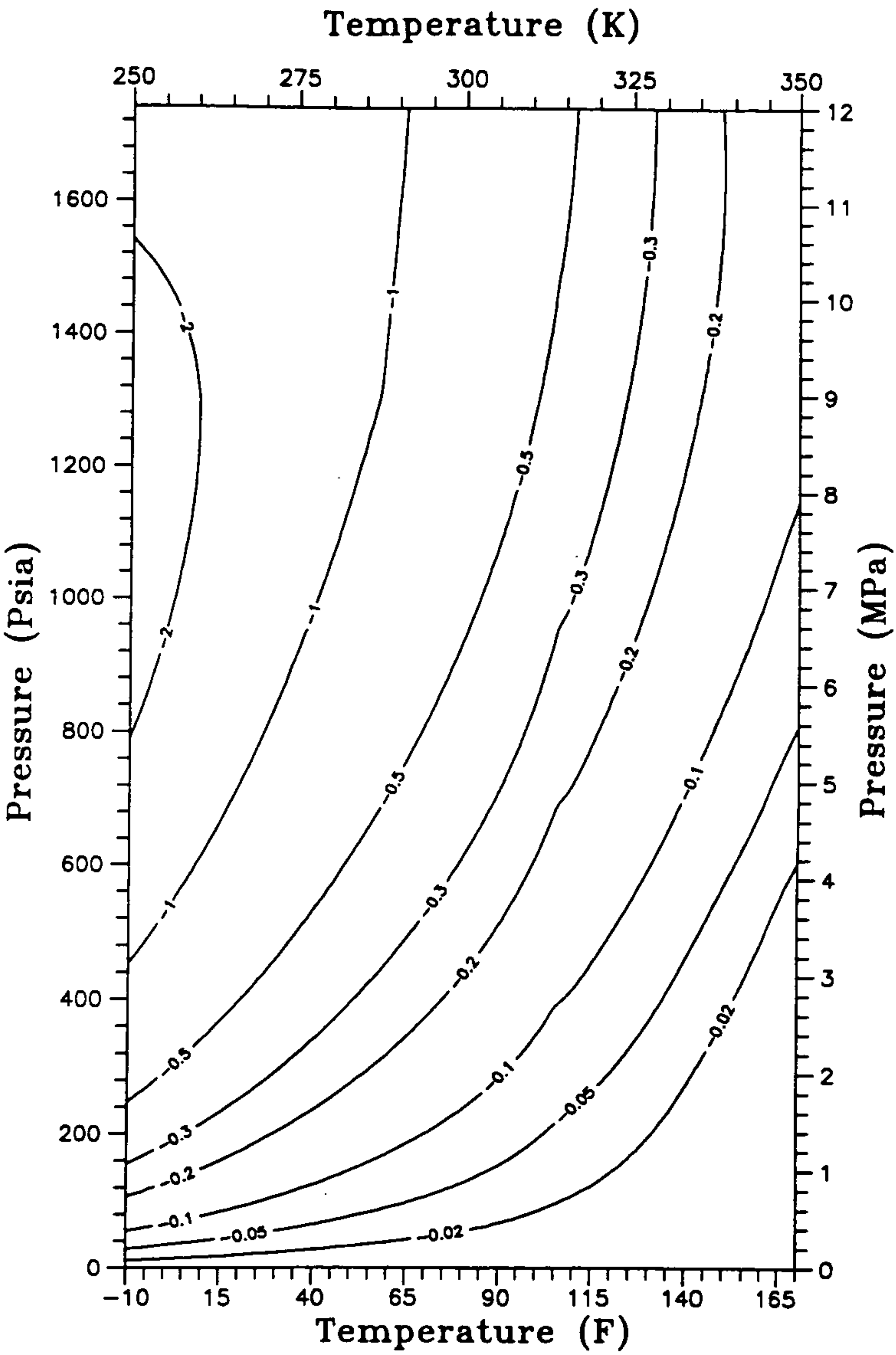

Figure 4. Deviation in Predicted Density Between the NX-19 Model and the Detail Characterization Method for Ekofisk Gas.

		STATFJORD FIELD	VESLEFRIKK FIELD
CH_4	Methane	73.21	66.5
N_2	Nitrogen	0.65	1.22
CO_2	Carbon Dioxide	0.90	3.5
C_2H_6	Ethane	11.97	12.45
C_3H_8	Propane	8.55	11.66
C_4H_{10}	Butane	3.19	3.94
C_5H_{12}	Pentane	0.83	0.57
	heavier Hydrocarbons	0.70	0.09

Figure 5. Percent molar composition of Natural Gas from the Statfjord and Veslefrikk Fields.

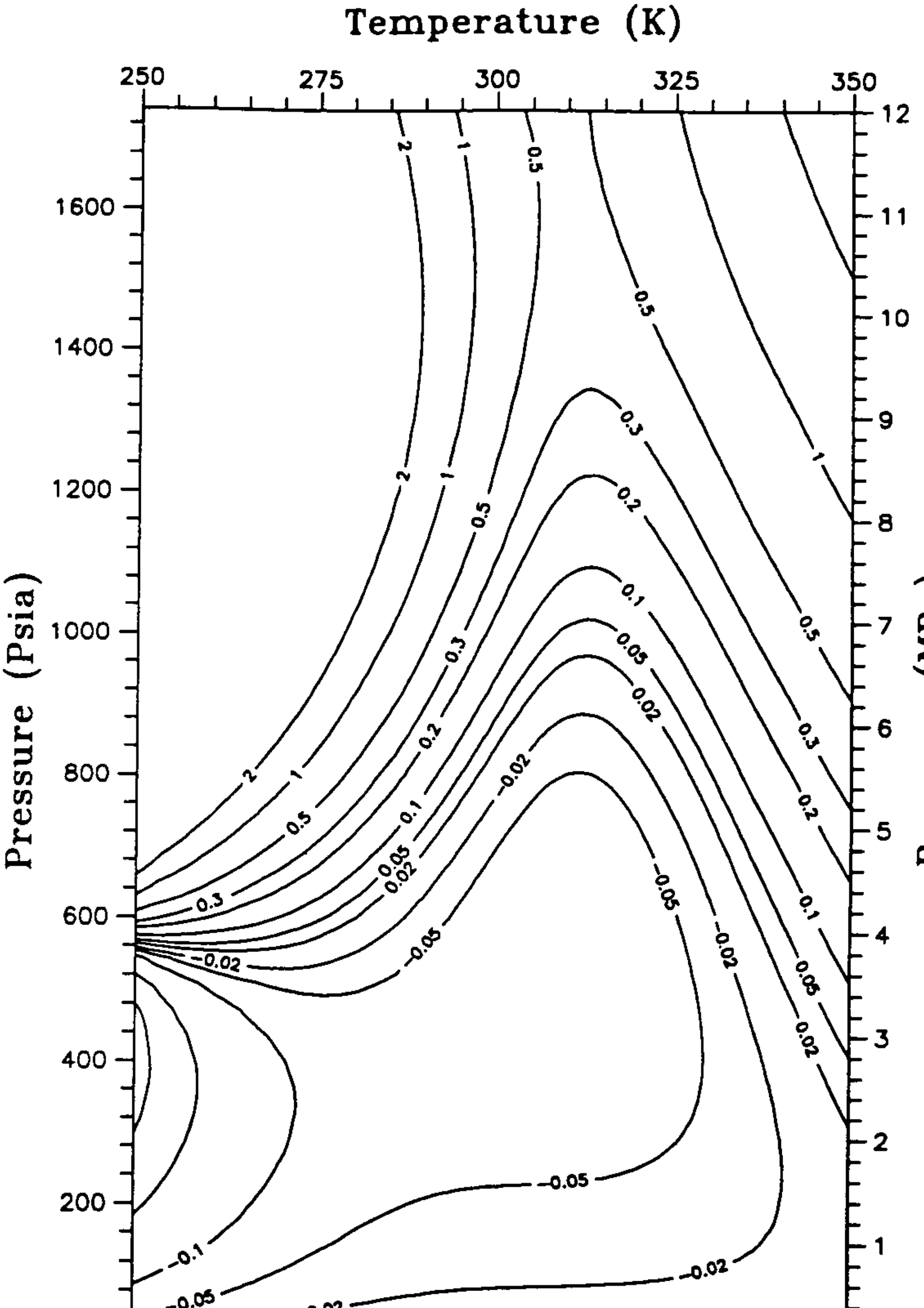

Figure 6. Deviation in Predicted Density between the Gross Characterization Method and the Detail Characterization Method for Statfjord Gas.

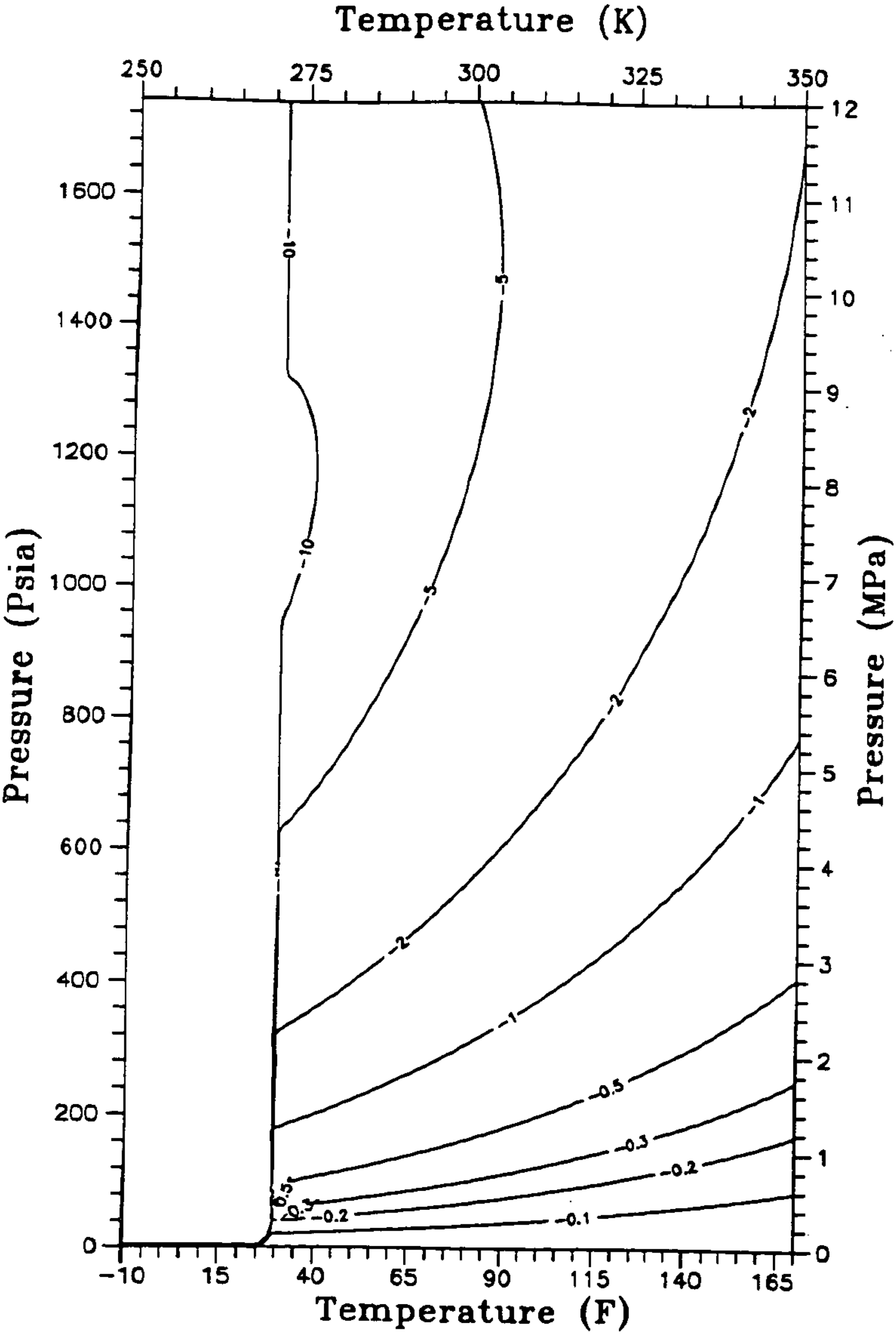

Figure 7. Deviation in Predicted Density between the NX-19 Model and the Detail Characterization Method for Statfjord Gas.

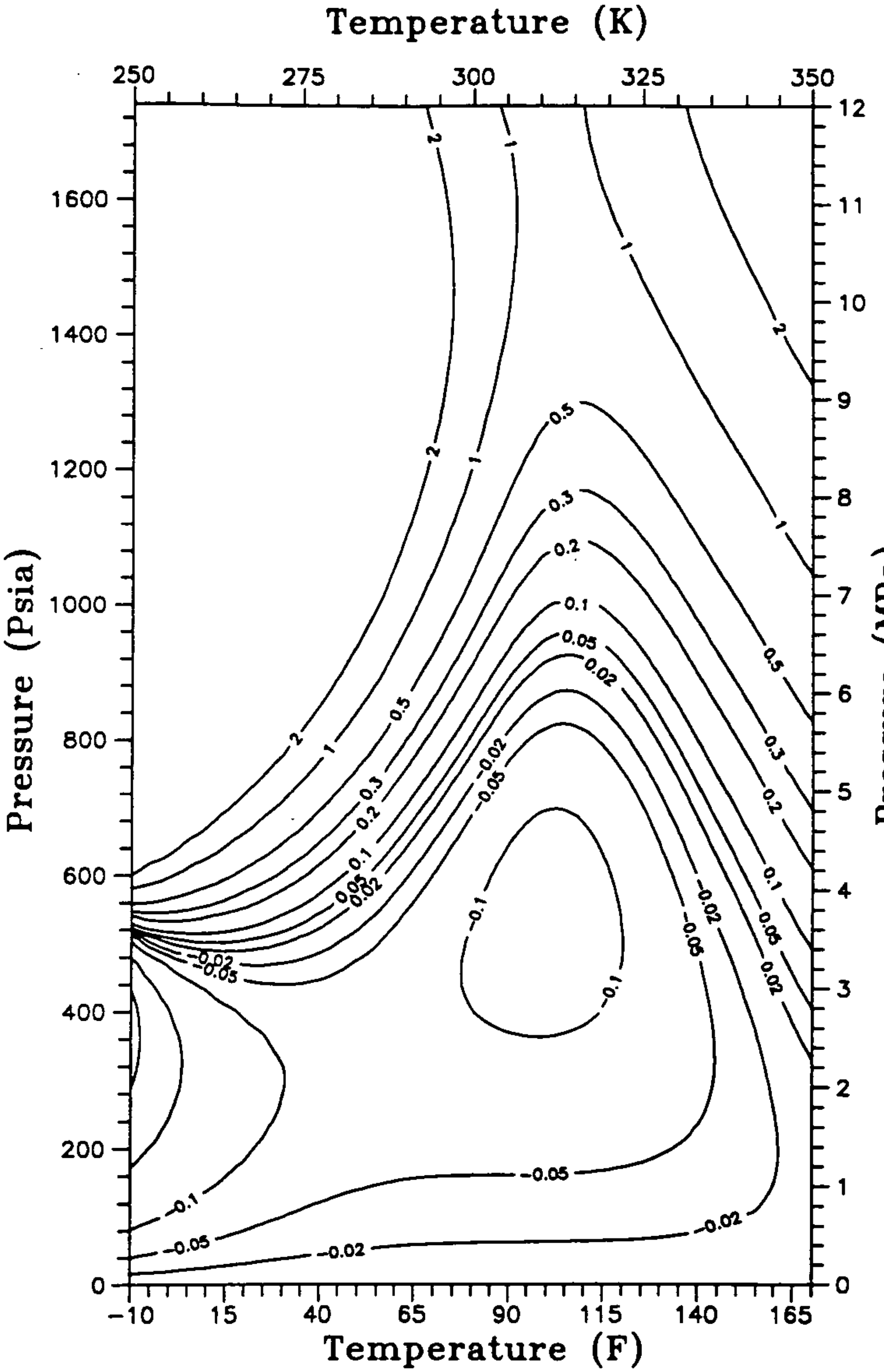

Figure 8. Deviation in Predicted Density between the Gross Characterization Method and the Detail Characterization Method for Veslefrikk Gas.

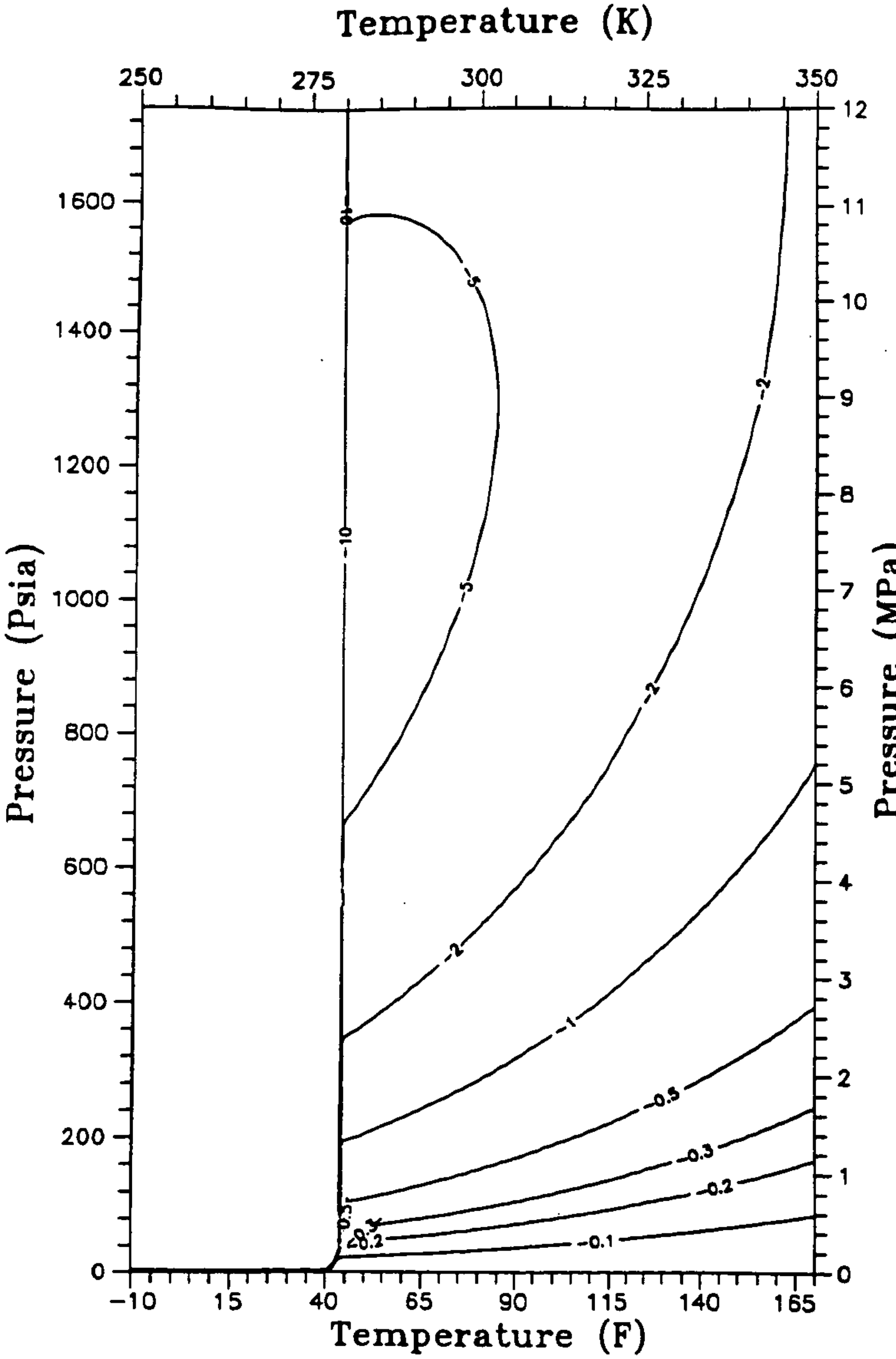

Figure 9. Deviation in Predicted Density between the NX-19 Model and the Detail Characterization Method for Veslefrikk Gas.