ACOUSTIC VELOCITY FOR NATURAL GAS

Introduction

Acoustic velocity data for natural gas is useful for determining liquid levels in oil or gas wells and locating obstructions in gas lines.

Application of Data

Generally the distance to the liquid level in an oil well is determined by generating a pressure wave in the casing annulus gas at the surface. The wave travels through the casing annulus gas to the liquid level which reflects the wave back to the surface. Generally, the depth is obtained by reference to obstructions in the annular space - the most common being collars, and/or liners, and/or perforations.

Sometimes however, the distance to the liquid level is determined by generating a pressure wave at the surface and measuring the time required for the wave to travel to the liquid level and back to the surface. With a knowledge of the acoustic velocity of the gas, the distance which the wave travelled (surface to liquid level to surface) is simply the time of travel multiplied by the acoustic velocity. The distance to the liquid level would be one half of the above or

$$D = \frac{T\,V}{2}$$

where

D = Distance to liquid level, ft.
T = Time between initial wave generation and reflected wave, sec.
V = Acoustic velocity, ft./sec.

The divisor of 2 is necssary because the distance to the liquid level is one-half of the total distance traveled by the pressure wave.

The acoustic velocity should be determined from the charts using the pressure and temperature at a depth of 1/2 of the distance to the liquid. The pressure at that depth can be estimated from data in reference No. 1. The temperature at that depth is often available or can be estimated from data given by P. L. Moses, reference No. 3.

Data presented herein is also beneficial for predicting acoustic velocity behavior. On some acoustic liquid level charts, the collars and/or liners are not recorded on the lower portion of the chart, and hence information on the behavior of acoustic velocity at the higher pressure and temperature is desirable.

Application of the data to acoustic well sounding is interesting. For example, assume a well with the liquid level at 10,000 feet, a surface temperature of 74^{o}F, a temperature of 194^{o}F at 10,000 feet, a gas gravity of 0.8 and a surface pressure of 100 PSIA. The acoustic velocity at the surface is 1145 ft./sec. The pressure increases with depth and the pressure at the liquid level is 132 PSIA. The acoustic velocity at 74^{o}F decreases to 1140 ft./ sec. with the increase of pressure. Assuming a constant pressure of 100 PSIA and a change of temperature to 194^{o}F results in an acoustic velocity of 1272 ft./sec. The acoustic velocity at liquid level conditions of 132 PSIA and 194^{o}F is 1268 ft./ sec. Thus the acoustic velocity is approximately 10.7% greater at the bottom of the well than at the surface.

Discussion of Graph Data

The acoustic velocity is given as functions of pressure and temperature for gas gravities of 0.6, 0.8, 1.0, and 1.2 at pressures from 0 to 3000 PSIA and normal operating temperatures of approximately 32°F (0°C) to 400°F (205° C).

Contrary to popular belief, the acoustic velocity decreases with an increase of pressure below pressures of approximately 1000 PSIA. Graphs covering a wider range of temperature and pressures are available from the author.

Note that the graphs indicate the normal rise in temperature with depth increases the acoustic velocity to a greater extent than the build up of pressure with depth decreases the acoustic velocity at pressures below approximately 1000 PSIA. At pressures above approximately 1000 PSIA, acoustic velocity increases with pressure.

Limitations of Application of Graphs to Acoustic Liquid Level Determination

In acoustic liquid level determination utilizing the time - acoustic velocity principle, special precautions must be applied. The time - acoustic velocity principle is best applied to wells or gas columns which have a uniform gas composition. Wells venting gas at the surface to atmosphere or to the flow line contain gas in the entire annular space of relatively uniform composition and an accurate acoustic velocity can be determined. If the well does not vent gas or the gas column has been shut in at the surface for a long time, a considerable difference in the composition of gas throughout the casing annulus can occur, and considerable difference in the acoustic velocity will occur. Acoustic velocity differences of 35% have been noted in individual wells. Also, if air has been permitted to enter the surface openings, a considerable difference in acoustic velocities will occur.

Source of Data

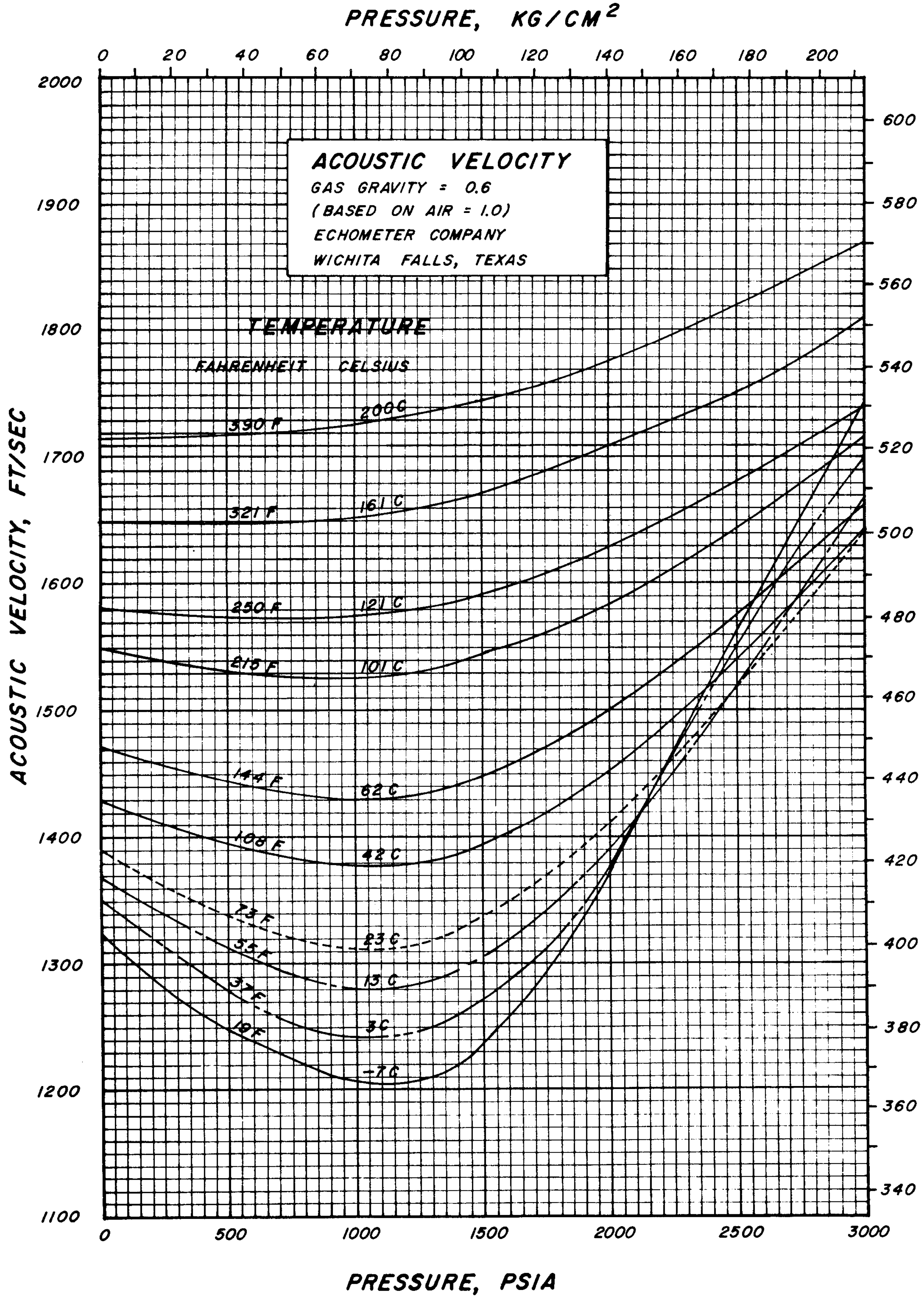
This data has been obtained from a paper given by L. K. Thomas[2]. The original work required a knowledge of the gas gravity, temperature and pressure. From this, the pseudocritical pressure, pseudocritical temperature, pseudo reduced pressure, and pseudo reduced temperature were calculated or determined. Then by use of graphs given in the paper the acoustic velocity could be determined. The graphs presented herein show the acoustic velocity as a function of pressure and temperature. The presented graphs should have an average error approaching 0.71 percent claimed in the original work.

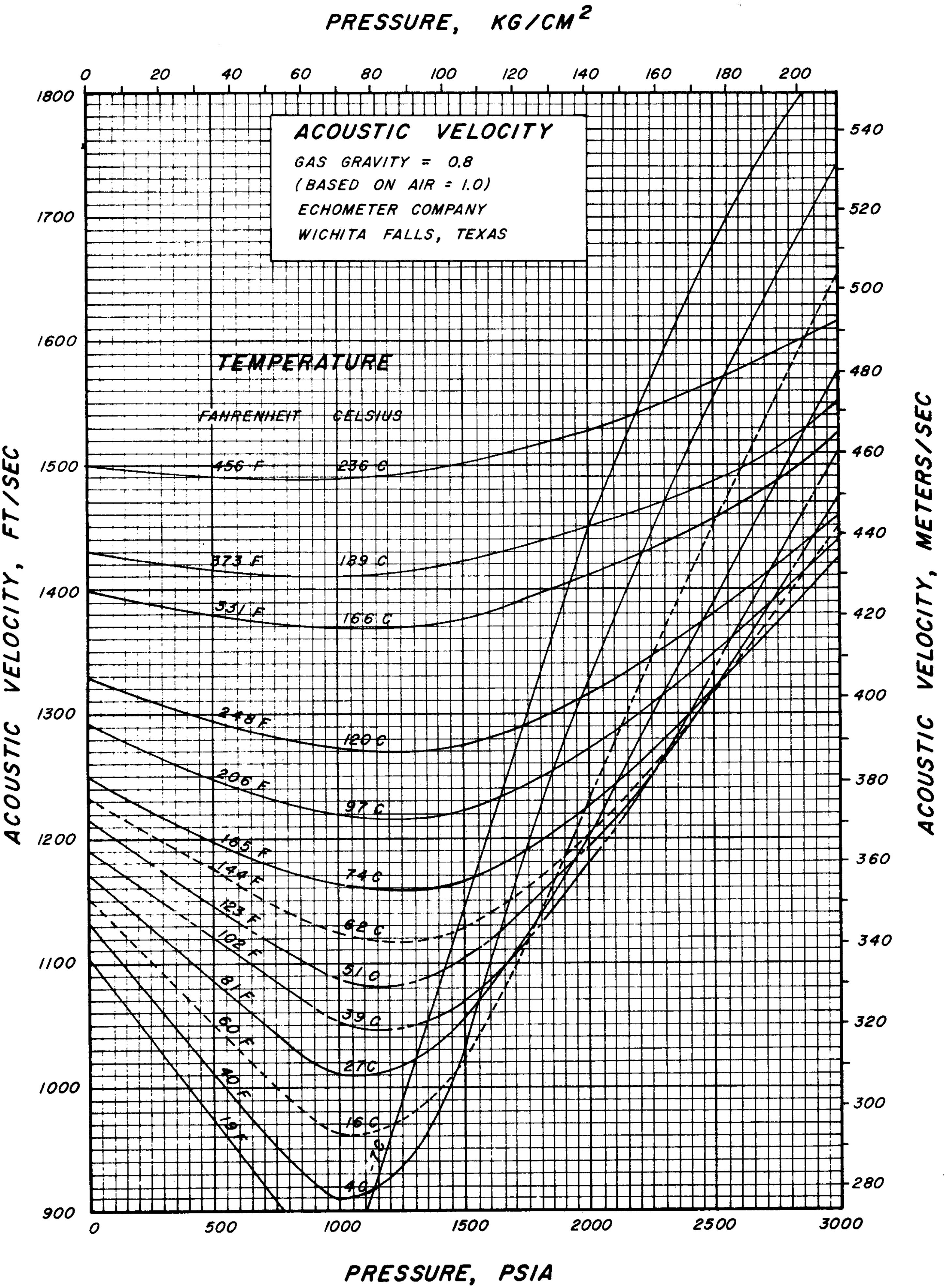
Acoustic Velocity of Dry Air

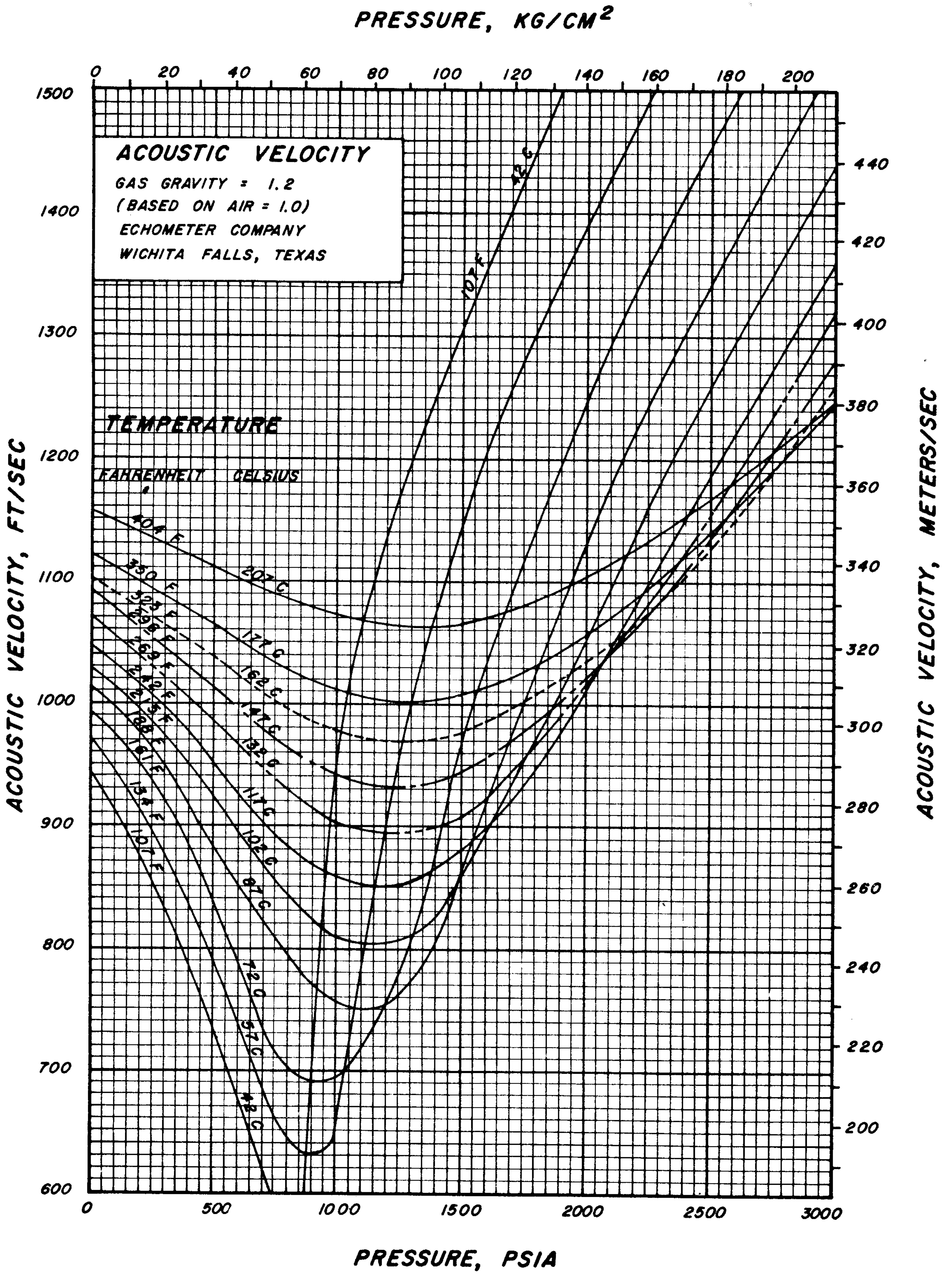
The acoustic velocity of dry air at 32°F (0° C) and standard pressure is 1087 ft./sec. (331.45 meters/sec.) and changes directly with temperature at the approximate rate of 1.075 ft./sec./'F (or 0.59 meters / sec. /°C.

References:

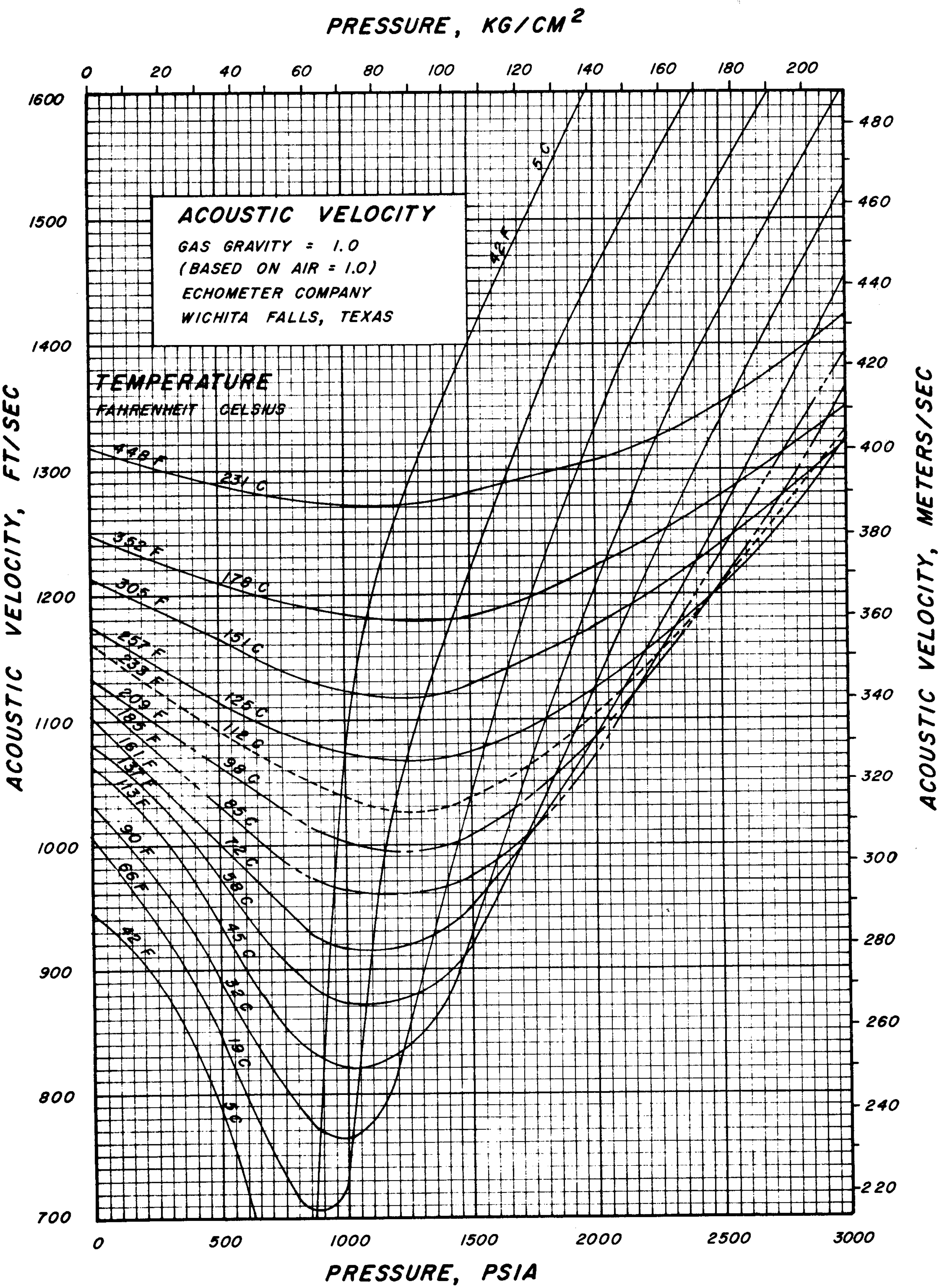
1. McCoy, James N., Analyzing Well Performance VI, Southwestern Petroleum Short Course Association, 1973, Lubbock, Texas. Available from Echometer Company, 5001 Ditto Lane, Wichita Falls, Texas 76302.
2. Thomas, Hankinson, & Phillips, Determination of Acoustic Velocities for Natural Gas, SPE #2579 of AIME
3. P. L. Moses, Geothermal Gradients, Drilling & Production Practice, (1961) available from Core Lob., Inc., Dallas, Texas


PRESSURE, KG/CM²
0
20
40
60
80
100
120
140
160
180
200
ACOUSTIC VELOCITY
GAS GRAVITY = 0.6
(BASED ON AIR = 1.0)
ECHOMETER COMPANY
WICHITA FALLS, TEXAS
TEMPERATURE
FAHRENHEIT CELSIUS
390 F 200 C
321 F 161 C
250 F 121 C
215 F 101 C
144 F 62 C
108 F 42 C
73 F 23 C
55 F 13 C
37 F 3 C
19 F -7 C
ACOUSTIC VELOCITY, FT/SEC
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
ACOUSTIC VELOCITY, METERS/SEC
600
580
560
540
520
500
480
460
440
420
400
380
360
340
0
500
1000
1500
2000
2500
3000
PRESSURE, PSIA


PRESSURE, KG/CM²
0
20
40
60
80
100
120
140
160
180
200
ACOUSTIC VELOCITY
GAS GRAVITY = 0.8
(BASED ON AIR = 1.0)
ECHOMETER COMPANY
WICHITA FALLS, TEXAS
TEMPERATURE
FAHRENHEIT
CELSIUS
456 F
236 C
373 F
189 C
331 F
166 C
248 F
120 C
206 F
97 C
165 F
74 C
144 F
62 C
123 F
51 C
102 F
39 C
81 F
27C
60 F
16 C
40 F
4C
19 F
-7C
ACOUSTIC VELOCITY, FT/SEC
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
ACOUSTIC VELOCITY, METERS/SEC
540
520
500
480
460
440
420
400
380
360
340
320
300
280
0
500
1000
1500
2000
2500
3000
PRESSURE, PSIA



PRESSURE, KG/CM²
0
20
40
60
80
100
120
140
160
180
200
ACOUSTIC VELOCITY
GAS GRAVITY = 1.2
(BASED ON AIR = 1.0)
ECHOMETER COMPANY
WICHITA FALLS, TEXAS
TEMPERATURE
FAHRENHEIT
CELSIUS
404 F
350 F
323 F
296 F
269 F
242 F
215 F
188 F
161 F
134 F
107 F
207 C
177 C
162 C
147 C
132 C
117 C
102 C
87 C
72 C
57 C
42 C
ACOUSTIC VELOCITY, FT/SEC
1500
1400
1300
1200
1100
1000
900
800
700
600
ACOUSTIC VELOCITY, METERS/SEC
440
420
400
380
360
340
320
300
280
260
240
220
200
0
500
1000
1500
2000
2500
3000
PRESSURE, PSIA



PRESSURE, KG/CM²
0
20
40
60
80
100
120
140
160
180
200
ACOUSTIC VELOCITY
GAS GRAVITY = 1.0
(BASED ON AIR = 1.0)
ECHOMETER COMPANY
WICHITA FALLS, TEXAS
TEMPERATURE
FAHRENHEIT CELSIUS
448 F
231 C
352 F
178 C
305 F
151 C
257 F
125 C
233 F
112 C
209 F
98 C
185 F
85 C
161 F
72 C
137 F
58 C
113 F
45 C
90 F
32 C
66 F
19 C
42 F
5 C
ACOUSTIC VELOCITY, FT/SEC
1600
1500
1400
1300
1200
1100
1000
900
800
700
ACOUSTIC VELOCITY, METERS/SEC
480
460
440
420
400
380
360
340
320
300
280
260
240
220
0
500
1000
1500
2000
2500
3000
PRESSURE, PSIA