Upstream LNG Technology
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Lecture – 23
Tutorial on temperature and quality measurement in natural gas

Welcome after learning about some techniques to estimate the pressure and the quality of natural gas we shall do some few problems on these. So, in this lecture we shall be learning that on Tutorial on temperature and quality measurements in natural gas.

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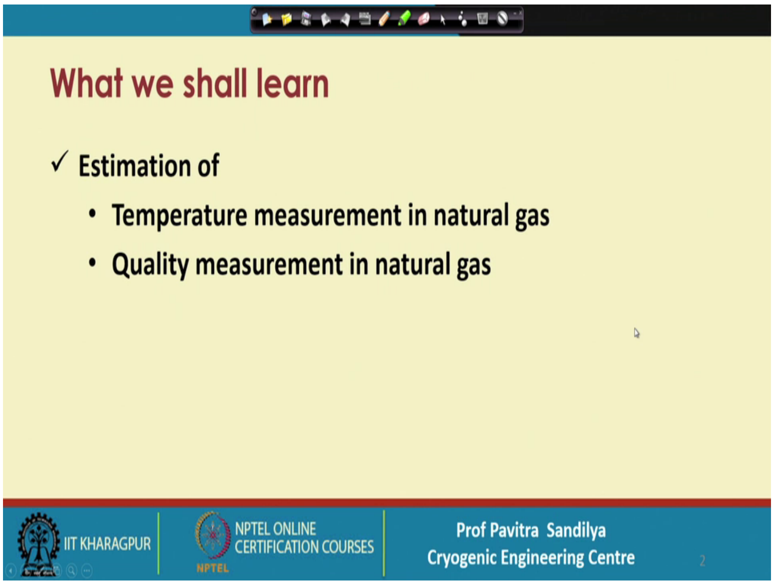

And we shall be learning about the estimation of temperature and the quality in natural gas.

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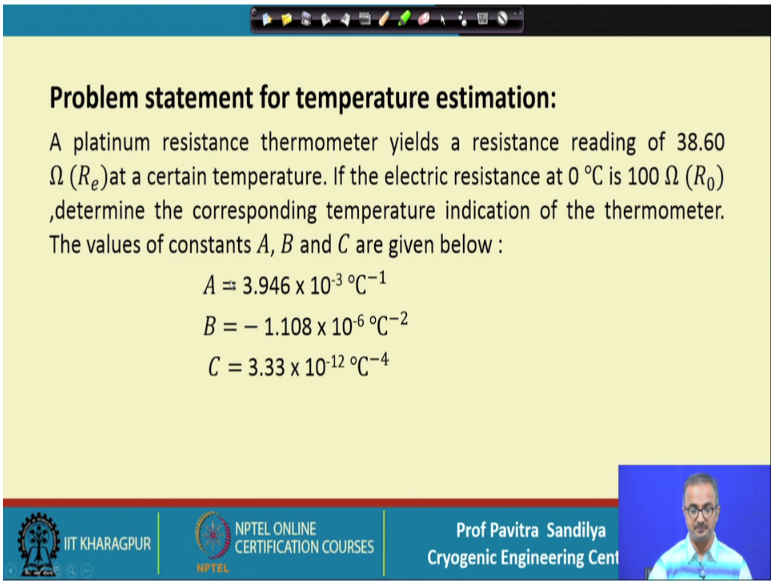

So, this is the first problem on the temperature estimation in this we have used a data from platinum resistance thermometer; which says that the, it gives a reading of about 38.60 ohms at certain temperature. And it is given that at 0 degree centigrade it is 100 ohms; that is this platinum resistance thermometer gives a resistance of 100 ohms at 0 degree centigrade. These 100 ohms is not fixed different platinum resistances may give different values of the resistance and because it is 100 ohms. So, this kind of resistance thermometer is called pt 100' pt stands for platinum and 100 stands for the resistance at 0 degree centigrade.

So; that means, we are using a pt 100 temperature sensor for this kind of a natural gas. So, this pt 100 gives a reading of 38.6 ohms at certain resistance certain temperature and this resistance is given by Re. And we have been given these values of the various coefficients which are used for the converting the, or correlating the resistance with the temperature for this platinum resistance thermometers.

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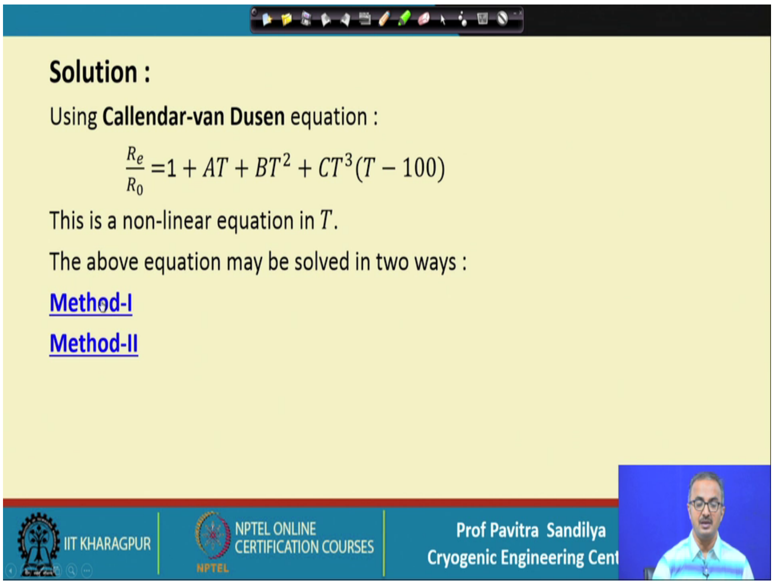

So, here this is the Callendar-van Dusen equation which takes this A B C and we find that in this expression the temperature is coming in terms of T to power 4; So, this quadratic expression which needs to be solved to find out the values of temperature for a given value of relative resistance that is Re by R naught. So, this is a non-linear equation in temperature; so, we may use some non-linear technique of problem with this root finding method, but. So, there are two types of method we can adopt for following this expression. So, let us go by first method.

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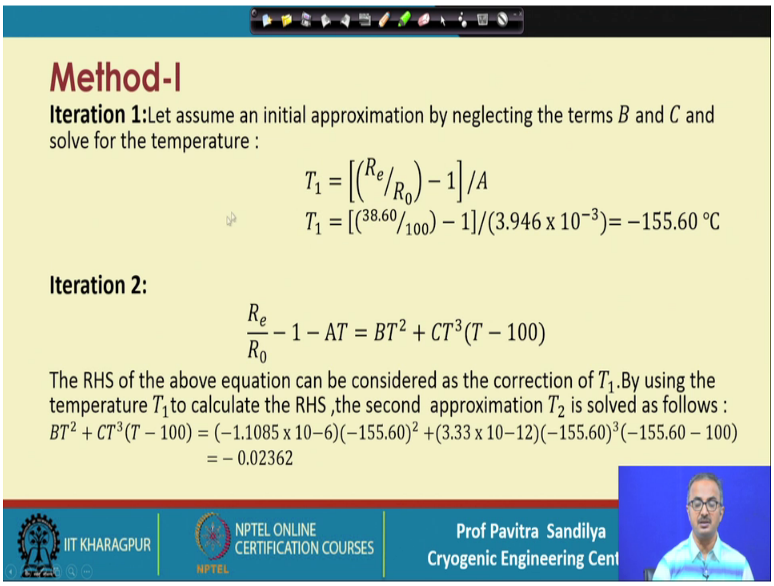

In the first method what we do we do not go for a root finding method, but we go for iterative method by substituting the value successively in an modified expression. So, what we start with is this we first neglect the non-linear terms in the van Dusen equation. And here we have this expression for temperature this temperature this T 1 represents the first iteration temperature and here we find this is the Re by R 0 minus one divided by A.

So, we put this linear expression to find out the value of for system is as minus 155.6 degree centigrade. And now because it is non-linear what we now do that we put these expressions for this just modify the equation a bit and we put the expression. And now what we do that this in the RHS; we put this value of this minus 155.6 and after putting this value again we find the value of the temperature as a second iterative temperature.

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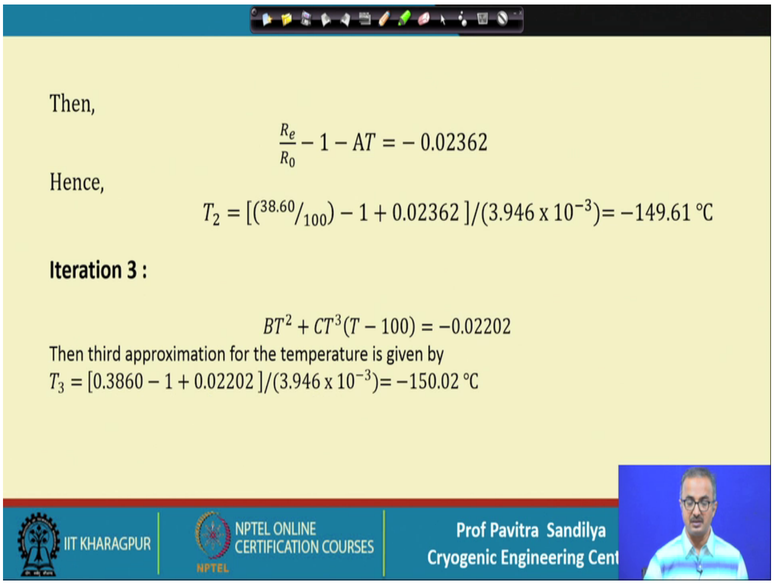

And then we find that this temperature gets modified to minus 149.61 degree centigrade now with this temperature again we go back to this expression; put this temperature values here and again we estimate this temperature. And; that way we keep on doing this iteration and ultimately we find that we are carrying out this iteration.

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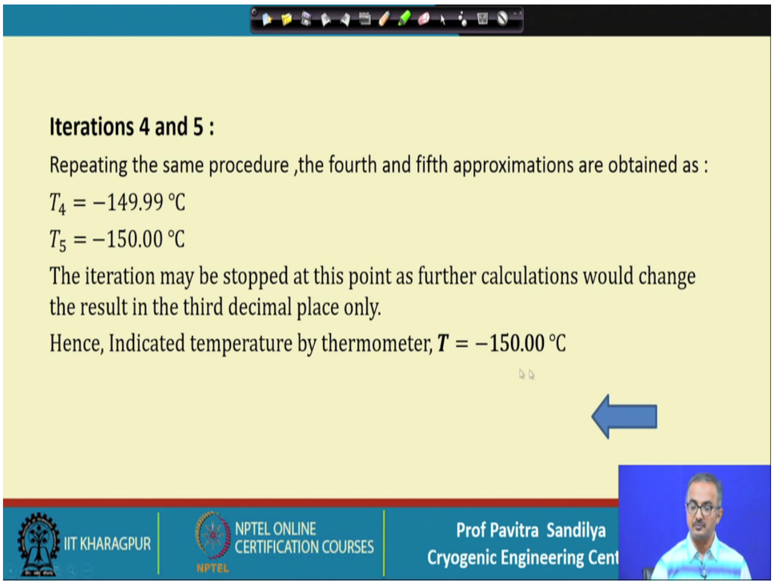

And we find in 4 or 5 iterations you almost approach a constant value and because these values are almost same. So, we take the final temperature to be minus 150 degree centigrade. So, this is a very simple method that where we linearize the expression and go for a substitution method successively to get the root of the equation; so, this is one of the ways.

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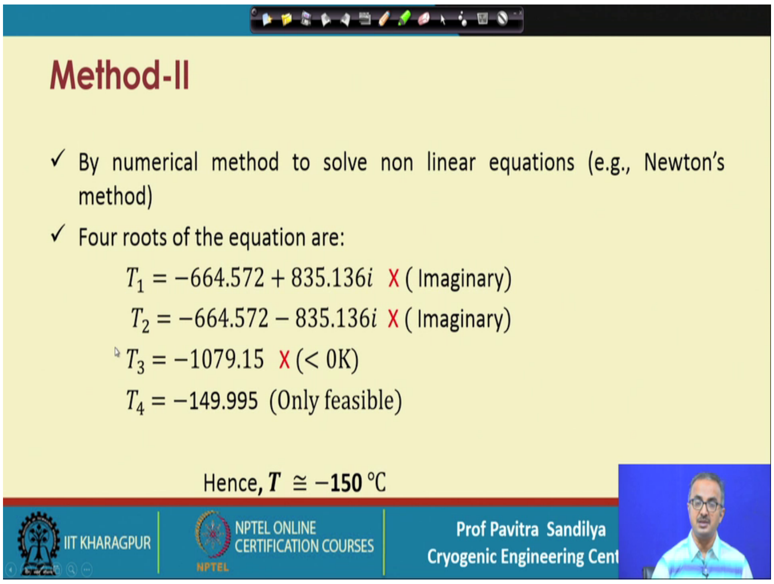

Now, we may also go for a direct solution of this quadratic equation and in this direct solution we can use a standard Newton's method and if I apply this method. And for solving this it you can do it either manually or you can code it you can also use MATLAB code to solve this expression. So, if you do it by manually or by some MATLAB or other Fortran code or some C plus plus code you will find that you get these 4 roots of the equation. So, these 4 roots are given by this and you find that first 2 roots are; obviously, not right because they are giving imaginary values. So, they are rejected and the third one is not imaginary, but the value see it is degree centigrade. So, this is much less than the 0 Kelvin.

So, we know that absolute temperature can never be below 0 Kelvin. So, this is also taken out only a fourth root is kind of feasible one. So, we take these approximately this is as one minus 150 degree centigrade. So, we see that by adopting two different methods we can arrive at the same value of the temperature. So, this tells us that it our actual solution does not depend or must not depend on the type of technique we are use using to solve these expressions non-linear expressions. So, with this we find that we get the temperature of the natural gas as minus 150 degree centigrade.

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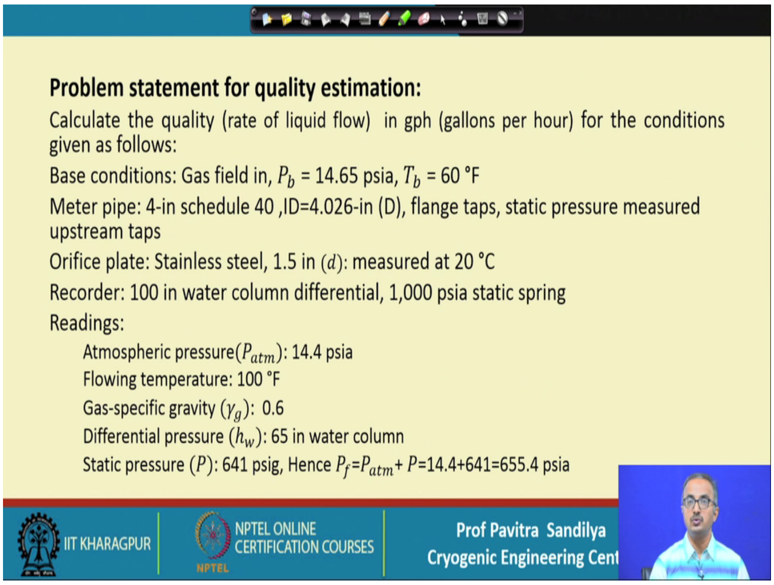

Now, we go to another problem on the quality estimation; when we say quality as we learnt earlier quality means that: what is the fraction of the liquid and vapor in the natural gas. And in this case we are defining the quality in terms of the amount of liquid.

So, in this problem we have been asked to determine the quality of natural gas in terms of rate of liquid flow in gph that is gallons per hour. Based on these field conditions and please note that these field conditions are the same as we did for the earlier solution for the finding the flow rate through orifice meter of natural gas. So, we have taken the same values here and we do many these unit convergence.

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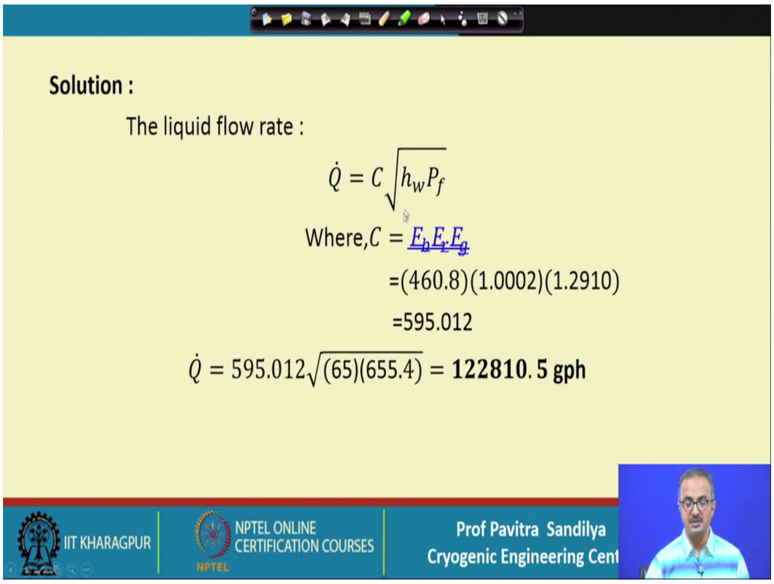

And we find that we get this expression for the liquid flow rate and here we have been given this value of C in terms of F b F r and F g. Now as we discussed under the flow rate for natural gas through orifice meter, we find that the same values of the correction factors F b, F r and F g are also used in this expression.

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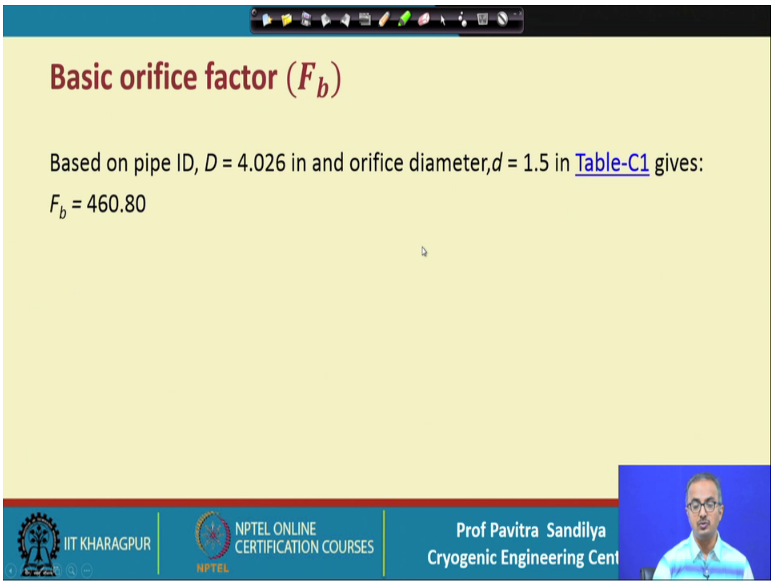

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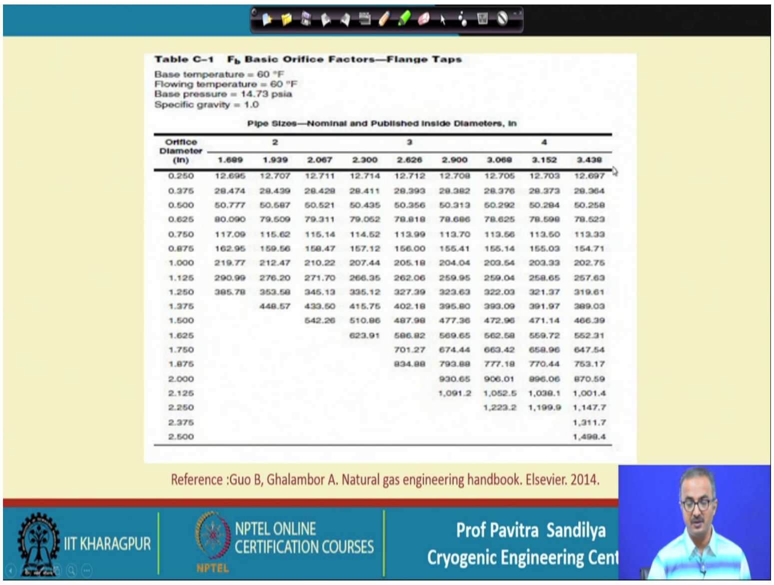

Table C–1 F_b Basic Orifice Factors—Flange Taps

Base temperature = 60 °F
Flowing temperature = 60 °F
Base pressure = 14.73 psia
Specific gravity = 1.0

Pipe Sizes—Nominal and Published Inside Diameters, in

Orifice Diameter (in)	2				3			4	
	1.689	1.939	2.067	2.300	2.626	2.900	3.068	3.152	3.438
0.250	12.695	12.707	12.711	12.714	12.712	12.708	12.705	12.703	12.697
0.375	28.474	28.439	28.428	28.411	28.393	28.382	28.376	28.373	28.364
0.500	50.777	50.587	50.521	50.435	50.356	50.313	50.292	50.284	50.258
0.625	80.090	79.509	79.311	79.052	78.818	78.686	78.625	78.598	78.523
0.750	117.09	115.62	115.14	114.52	113.99	113.70	113.56	113.50	113.33
0.875	162.95	159.56	158.47	157.12	156.00	155.41	155.14	155.03	154.71
1.000	219.77	212.47	210.22	207.44	205.18	204.04	203.54	203.33	202.75
1.125	290.99	276.20	271.70	266.35	262.06	259.95	259.04	258.65	257.63
1.250	385.78	353.58	345.13	335.12	327.39	323.63	322.03	321.37	319.61
1.375		448.57	433.50	415.75	402.18	395.80	393.09	391.97	389.03
1.500			542.26	510.86	487.98	477.36	472.96	471.14	466.39
1.625				623.91	586.82	569.65	562.58	559.72	552.31
1.750					701.27	674.44	663.42	658.96	647.54
1.875					834.88	793.88	777.18	770.44	753.17
2.000						930.65	906.01	896.06	870.59
2.125						1,091.2	1,052.5	1,038.1	1,001.4
2.250							1,223.2	1,199.9	1,147.7
2.375									1,311.7
2.500									1,498.4

So, we go to this expression for F b and F b is obtained from this particular chart; here we have the orifice diameter. And here we have nominal diameter of the pipe depending on that we find out the value of the this factor. And this can be obtained from this particular reference here and we get the value of the F b for this.

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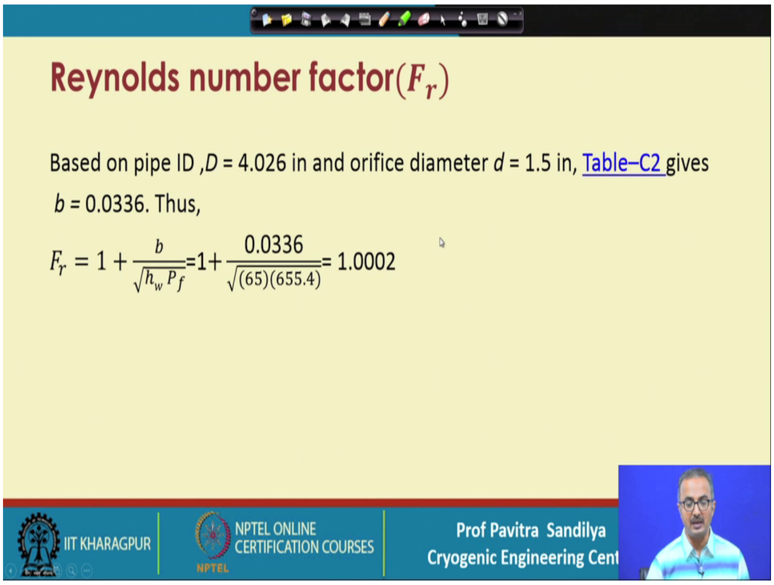

And then we go for another chart for F r this F r has been obtained from this particular chart.

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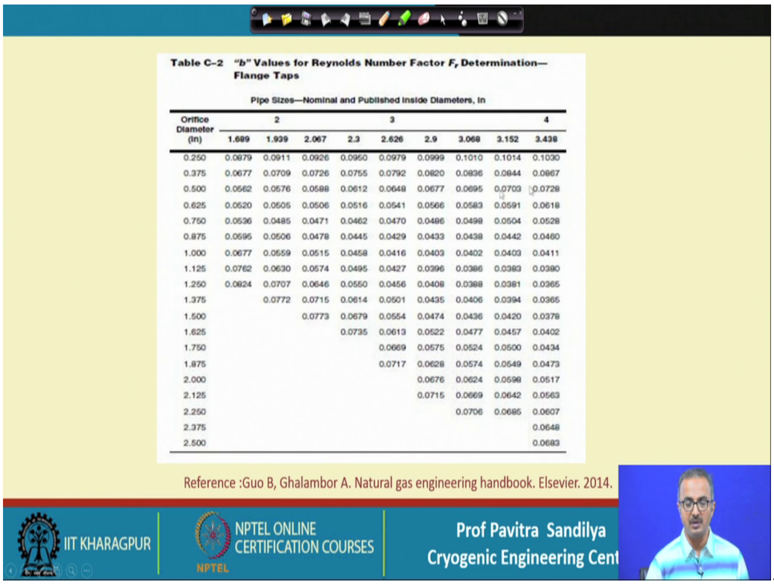

Table C–2 "b" Values for Reynolds Number Factor F_r Determination—Flange Taps

Pipe Sizes—Nominal and Published Inside Diameters, in

Orifice Diameter (in)	2			3					4
	1.689	1.939	2.067	2.3	2.626	2.9	3.068	3.152	3.438
0.250	0.0879	0.0911	0.0926	0.0950	0.0979	0.0999	0.1010	0.1014	0.1030
0.375	0.0677	0.0709	0.0726	0.0755	0.0792	0.0820	0.0836	0.0844	0.0867
0.500	0.0562	0.0576	0.0588	0.0612	0.0648	0.0677	0.0695	0.0703	0.0728
0.625	0.0520	0.0505	0.0506	0.0516	0.0541	0.0566	0.0583	0.0591	0.0618
0.750	0.0536	0.0485	0.0471	0.0462	0.0470	0.0486	0.0498	0.0504	0.0528
0.875	0.0595	0.0506	0.0478	0.0445	0.0429	0.0433	0.0438	0.0442	0.0460
1.000	0.0677	0.0559	0.0515	0.0458	0.0416	0.0403	0.0402	0.0403	0.0411
1.125	0.0762	0.0630	0.0574	0.0495	0.0427	0.0396	0.0386	0.0383	0.0380
1.250	0.0824	0.0707	0.0646	0.0550	0.0456	0.0408	0.0388	0.0381	0.0365
1.375		0.0772	0.0715	0.0614	0.0501	0.0435	0.0406	0.0394	0.0365
1.500			0.0773	0.0679	0.0554	0.0474	0.0436	0.0420	0.0378
1.625				0.0735	0.0613	0.0522	0.0477	0.0457	0.0402
1.750					0.0669	0.0575	0.0524	0.0500	0.0434
1.875					0.0717	0.0628	0.0574	0.0549	0.0473
2.000						0.0676	0.0624	0.0598	0.0517
2.125						0.0715	0.0669	0.0642	0.0563
2.250							0.0706	0.0685	0.0607
2.375									0.0648
2.500									0.0683

Again it depends on the orifice meter and nominal size of the pipe and the gauge of the pipe. So, this from this particular chart we locate the orifice diameter, the nominal diameter, the gauge and we find out the value of the factor F r.

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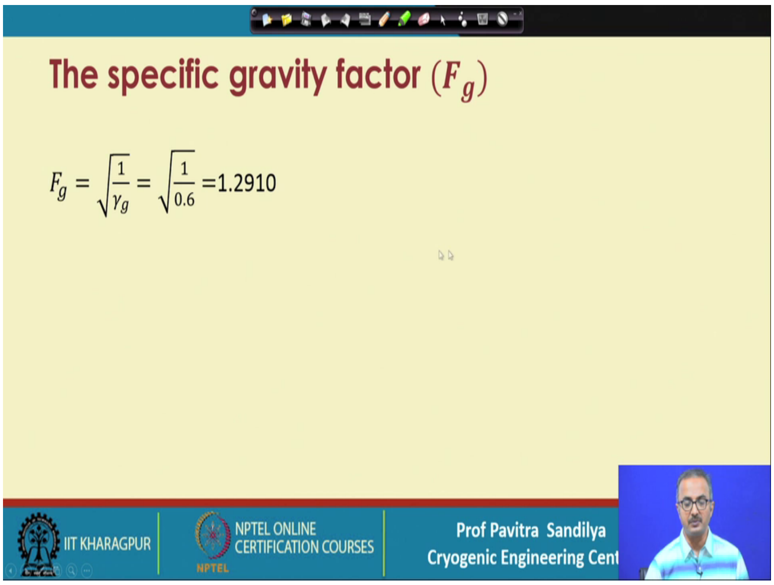

And then lastly we have the value of the F g, this obtained from the specific gravity which we also find out earlier and this is coming as 1.2910. So, with these values what we do now? We have all the values with us and we plug in the values over here to find out the value of C. And this C value is then plugged in into this expression and h w P f are given in the, a problem this is h w is the height of the water column. And with this we will find that the liquid flow rate in the natural gas is coming out to be 122810.5o gallons per hour.

So, this is the flow rate of the liquid once we know the flow rate of the liquid and once we know the gas flow rate now we can take the appropriate ratio to find out the fraction of the liquid in the natural gas. And that is how we represent the quality of the, what natural gas in terms of the liquid flow rate.

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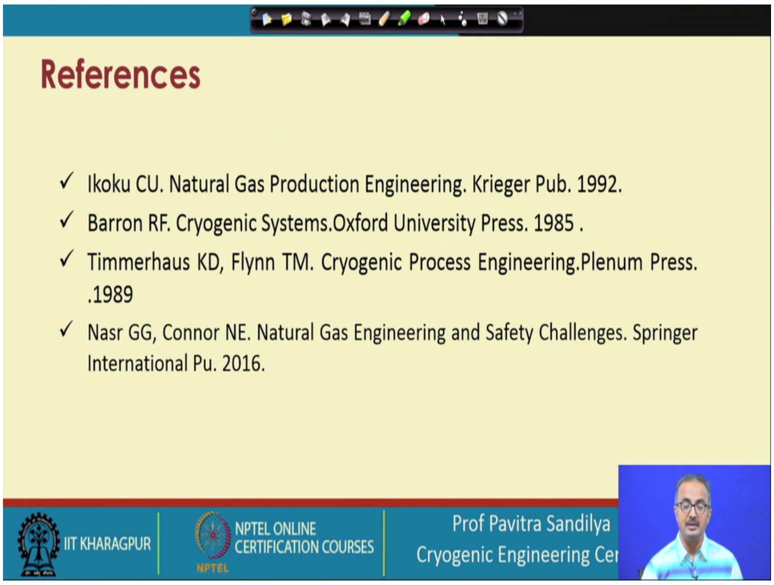

And these are the some references from which you can get the more detailing and the data to solve the, but this temperature as well as the quality of the natural gas.

Thank you.