Chemical Process Instrumentation
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Lecture – 33
Temperature Measurement (Contd.)

Welcome to lecture 33 of week 7, we have started our discussion on temperature measuring instruments. In our previous class, we have talked about how to classify various temperature measuring instruments, and then we started our discussion on thermal expansion method of temperature measurements, and we talked about bimetallic thermometer. Today will talk about temperature measuring instruments based on thermal expansion of liquid.

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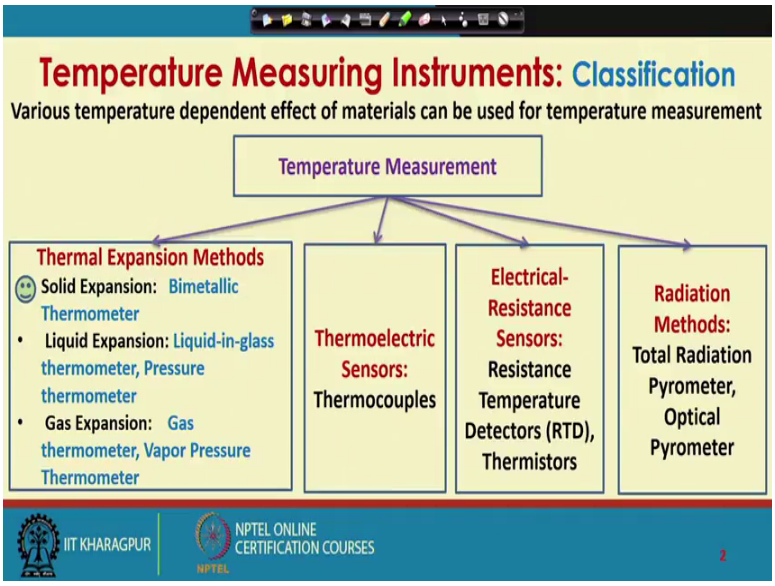

So, we have looked this classification of various temperature measuring instruments. Under thermal expansion methods we have talked about bimetallic thermometer, and today we will talk about liquid expansion thermometers.

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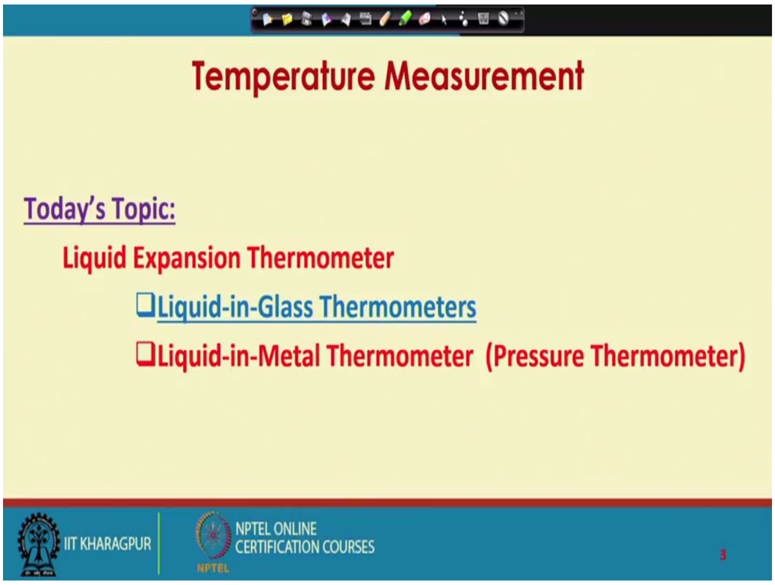

So, today's topic will be liquid expansion thermometers; under liquid expansion thermometers we have liquid in glass thermometers and liquid in metal thermometers. Liquid in metal thermometers are also known as pressure thermometers. Today we will talk about liquid in glass thermometers.

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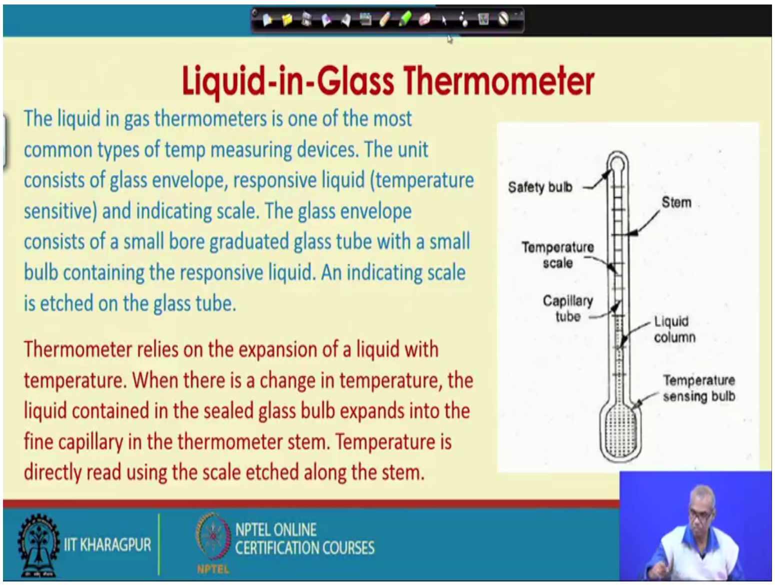

A liquid in glass thermometer is schematically shown in the diagram. The liquid in glass thermometer is one of the most common types of temperature measuring devices.

So, this is glass, the liquid in glass thermometers is one of the most common types of temperature measuring devices, the unit consists of glass envelope a responsive liquid known as temperature sensitive liquid, and an indicating scale. The glass envelope consists of small bore graduated glass tube with a small bulb containing the responsive liquid, and indicating scale is etched on the glass tube. So, you have a very simple construction, you have a glass envelope the glass envelope has a bulb, and has a stem and there is a capillary inside and a scale is etched on this stem.

Some thermometers are provided a safety bulb at the other end of the device. The thermometer relies on the expansion of a liquid with temperature, when there is a change in temperature the liquid contained in the sealed glass tube; glass bulb expands into the fine capillary in the thermometer stem. Temperature is then directly read using the scale etched along the stem. So, when you want to measure the temperature of a medium, you put this bulb into the medium whose temperature you want to measure. Then the liquid inside the bulb which is known as temperature sensitive liquid or responsive liquid receives thermal energy of the medium under goes a volume extension.

The volume expansion in liquid will be much more than the volume expansion of the glass. So, there will be restrict to thermal expansion a pressure will be developed, and that will cause the liquid label to be pushed up in this capillary. So, a scale is etched directly on the capillary or the stem of the thermometer, and we directly read the reading from the scale.

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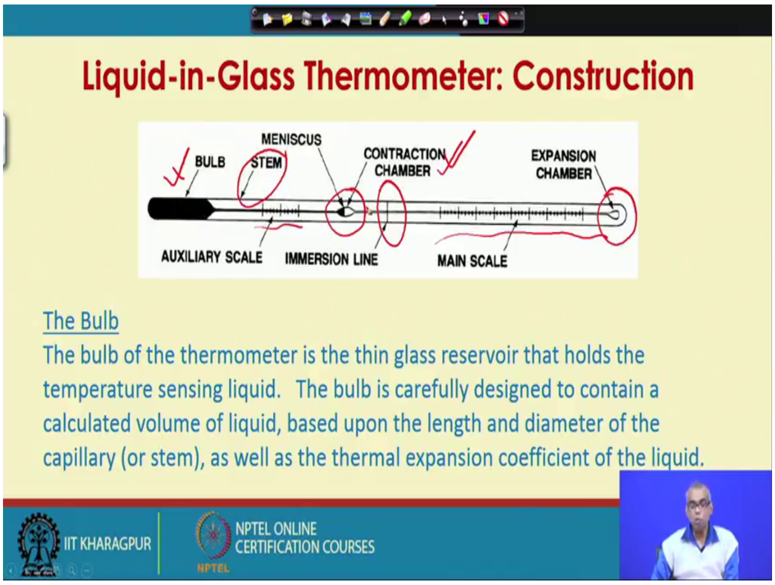

Now, let us look at the construction of liquid in glass thermometer in some more details. What is shown is, a little more details of the liquid in glass thermometer. So, you have bulb, this is stem or capillary, sometimes there is small chamber here or small deserver here, known as contraction chamber and also sometimes there is a small deserver or chamber at the other end of the thermometer known as expansion chamber.

Sometimes this expansion chamber is also known as safety bulb. This is the main scale which may be in degree Celsius or degree Fahrenheit, and sometimes an auxiliary scale is attached here which is always below the main scale. Some thermometers indicate a mark on the stem, which is known as immersion line. So, now, we will talk about these in little more details.

So, we will start with the bulb. The bulb of the thermometer is the thin glass reservoir that holds the temperature sensing liquid. The bulb is carefully designed to contain a calculated volume of liquid based upon the length and diameter of the capillary or stem as well as the thermal expansion coefficient of the liquid. So, bulb basically is a reservoir for the temperature sensitive liquid, and the volume of the bulb has to be carefully calculated based on the length and diameter of the capillary, and also based on thermal expansion coefficient of the liquid.

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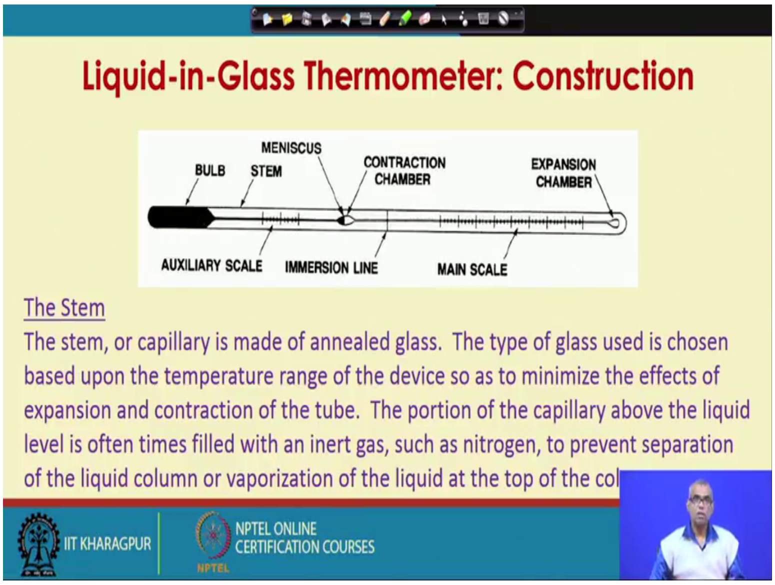

Next the stem the stem or capillary is made of annealed glass. The type of glass used is chosen based upon the temperature range of the device, so, as to minimize the effects of expansion and contraction of the tube. The portion of the capillary above the liquid level is often times filled with an inert gas such as nitrogen, to prevent separation of the liquid column or vaporization of the liquid at the top of the column.

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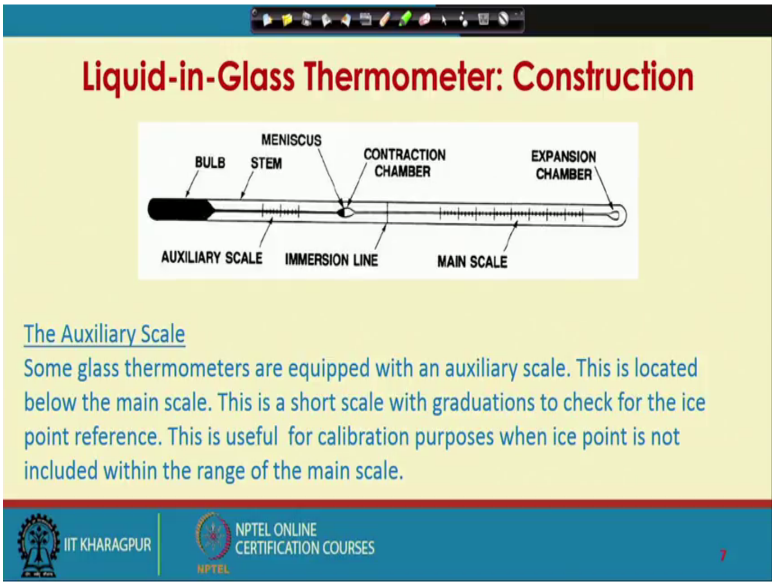

Next the auxiliary scale. Some glass thermometers are equipped with an auxiliary scary not all thermometer are provided with an auxiliary scale. This is located below the main scale this is a short scale with graduations to check for the ice point reference. This is useful for calibration purposes when ice point is not included within the main scale.

So, if the ice point is included within the range of main scale, then the auxiliary scale is not provided.

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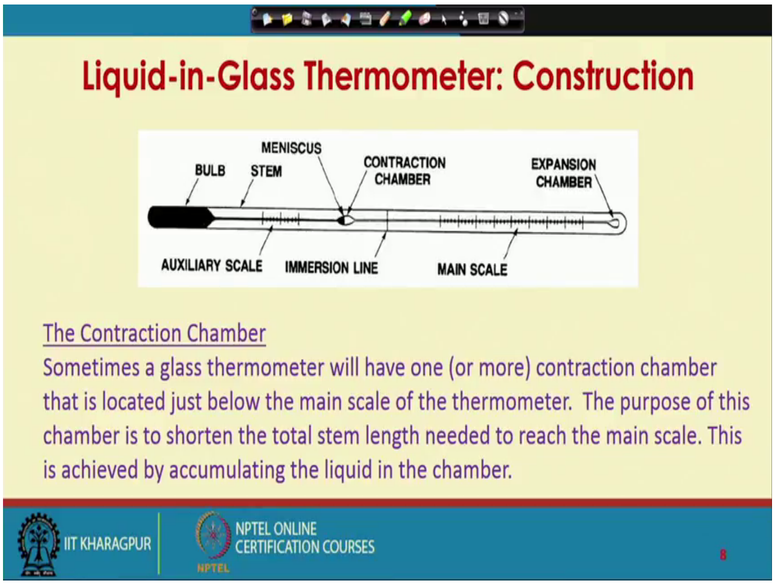

Next the contraction chamber; sometimes a glass thermometer will have one or more contraction chamber, that is located just below the main scale of the thermometer. The purpose of this chamber is to shorten the total stem length needed to reach the main scale; this is achieved by accumulating the liquid in the chamber. So, there is no contraction chamber the length of the thermometer may increase particularly for measurement of high temperatures.

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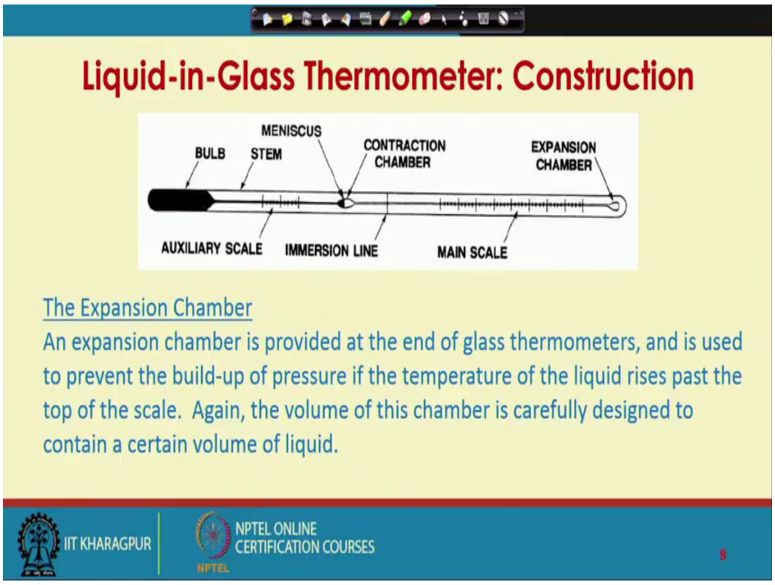

The expansion chamber or also known as safety bulb; the expansion chamber or the safety bulb is provided at the end of glass thermometers, and is used to prevent the buildup of pressure if the temperature of the liquid rises past the top of the scale. Again the volume of this chamber is carefully designed to contain a certain volume of liquid.

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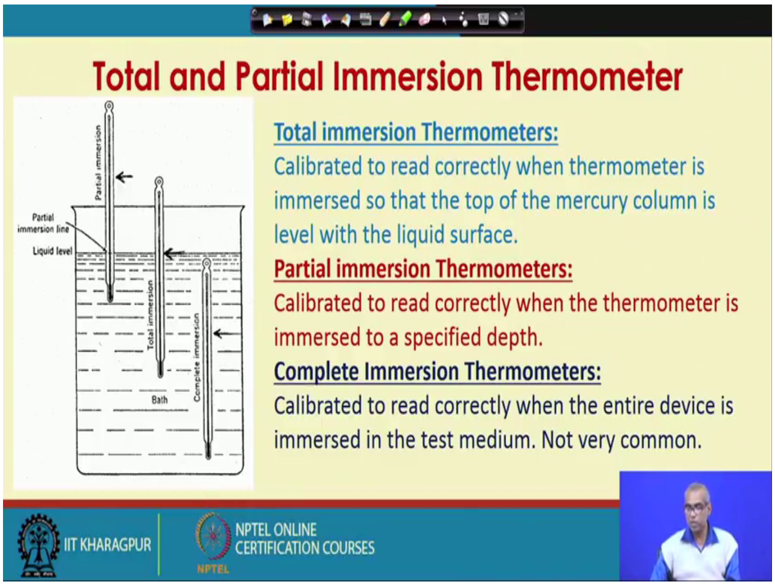

Now, there are 3 types of thermometers known as partial immersion thermometers, total immersion thermometers and complete immersion thermometers.

Partial immersion thermometers is indicated here. So, you will a partial immersion line indicated on the stem of the thermometer. And while measuring the temperature of the liquid say taken in bath, I must match the immersion line with the liquid level. Similarly for total immersion and complete immersion also there are standard procedures, which needs to be followed. So, let us look at that in some more detail. Total immersion thermometers are calibrated to read correctly when thermometer is immersed so that the top of the mercury column is level with the liquid surface. So, this is how we must measure the temperature say of the liquid in this bath using a total immersion thermometer.

Top of the mercury column must be in level with the liquid surface for total immersion thermometers; otherwise there will be an immersion error. Partial immersion thermometers are calibrated to read correctly when the thermometer is the immersed to a specified depth. Often times this is 76 millimeter, this partial immersion line is always indicated on the stem of the partial immersion thermometers. So, while measuring the temperature using a partial immersion thermometer, we must immerse the thermometer to the specified or indicated immersion line, otherwise there will be immersion error. Complete immersion thermometers are calibrated to read correctly, when the entire device is immersed in the test medium.

Total immersion thermometers and partial immersion thermometers are more common compared to complete immersion thermometers.

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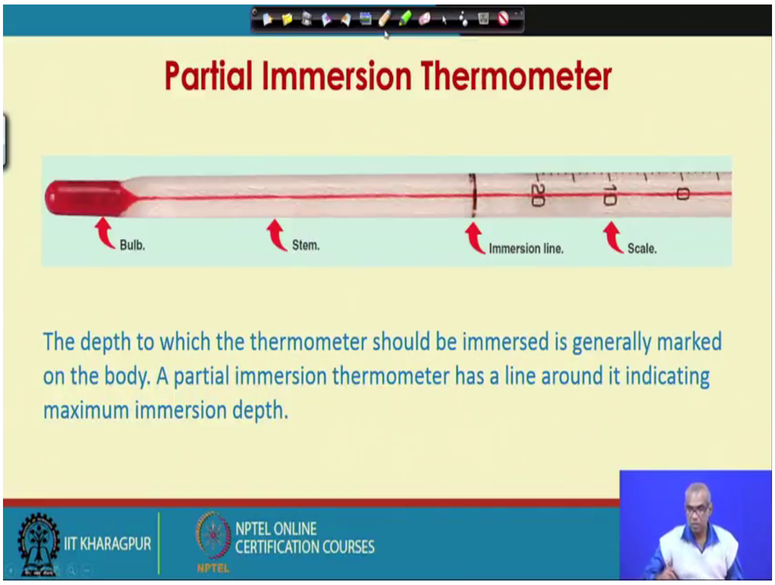

So, this is an image of partial immersion thermometer and this is the immersion line indicated on the stem of the thermometer. The depth to which the thermometer should be immersed is generally marked on the body; a partial immersion thermometer has a line around it indicating maximum immersion depth. If you do not follow this there will be an immersion error and there are vice to account for this error, we will talk about that. Incorrect immersion of thermometers so, how do I correct for this.

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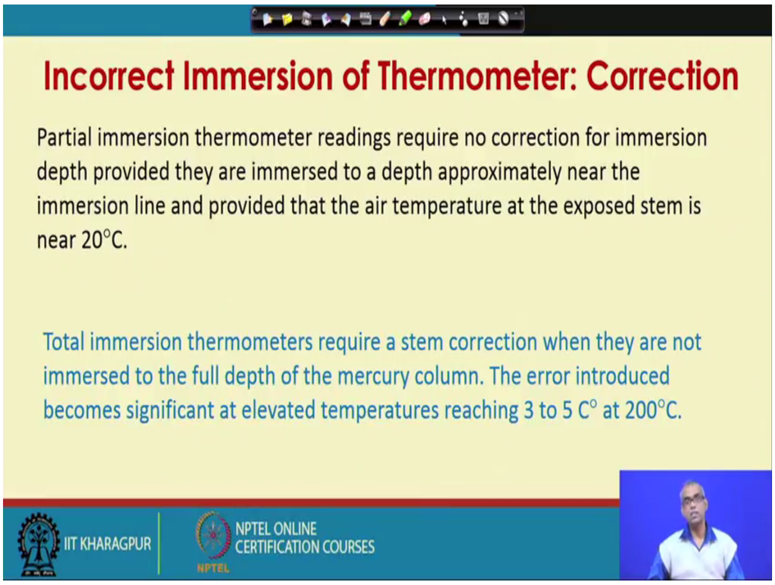

Partial immersion thermometer readings require no correction for immersion depth provided, they are immersed to depth approximately near the immersion line and provided that the air temperature at the exposed stem is near 20 degree Celsius. So, if I take partial immersion thermometer and immerse it to the date near the indicated depth, and the temperature of the surrounding to which the stem is exposed is near around 20 degree Celsius, no correction is needed. Total immersion thermometers require a stem correction when they are not immersed to the full depth of the mercury column.

The error introduced becomes significant at elevated temperatures reaching 3 to 5 degree Celsius, at 200 degree Celsius. So, at elevated temperatures or higher temperatures, the error introduced due to in correct immersion for total immersion thermometers becomes significant and at 200 degree Celsius it will be 3 to 5 degree Celsius.

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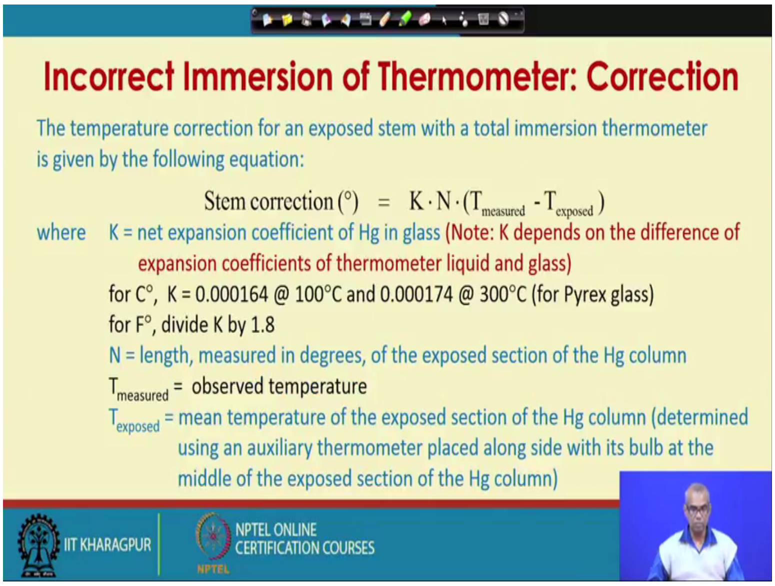

Now, let us look at an equation that we can use to correct for the immersion error. The temperature correction for an exposed stem with a total immersion thermometer is given by the equation as shown. Stem correction is K times N times T measured minus T exposed. K is net expansion coefficient of mercury in glass.

Let us say we talking about a partial as a total immersion thermometer, where the temperature sensitive liquid is mercury. So, K is the net expansion coefficient of mercury in glass. So, this takes care of expansion coefficient of mercury as well as expansion coefficient of glass. So, K depends on the difference of expansion coefficients of thermometer liquid and glass. For degree Celsius k equal to 0.000164 at 100 degree Celsius and 0.000174 at 300 degree Celsius for Pyrex glass.

For degree Fahrenheit you can divide these values by 1.8. So, K is described now what is N? N is length of the exposed section of the mercury column, and this is measured in degrees. So, N is length of the exposed section of the mercury column expressed in degrees. T measured is the observed temperature or temperature indicated by the thermometer and T exposed is the mean temperature of the exposed section of the mercury column, which has to be determined using an auxiliary thermometer placed alongside with its bulb at the middle of the exposed section of the mercury column.

So, please note that T measured is the observed temperature or indicated temperature by the thermometer and T exposed is the mean temperature of the exposed section of the mercury column, which you can determined using an auxiliary thermometer placed alongside with its bulb at the middle of the exposed section of the mercury column. So, you have to place the bulb of the auxiliary thermometer at the middle of the exposed section of the mercury column.

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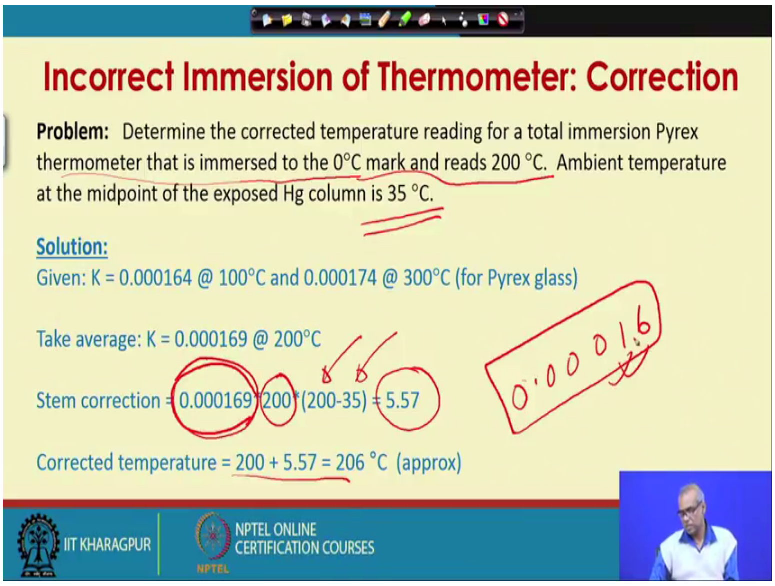

Now, let us take small problem to clarify this incorrect immersion of thermometers, and how to correct for this. Determine the corrected temperature reading for a total immersion Pyrex thermometer that is immersed to the 0 degree Celsius mark, and reads 200 degree Celsius. Ambient temperature at the midpoint of the exposed mercury column is 35 degree Celsius. So, basically all the information are given, we have to we need to know capital K which is the net thermal expansion coefficient those values have been indicated in previous slides, capital N and T measure minus T exposed.

So, the K values are given at 100 degree Celsius and 300 degree Celsius you are talking about 200 degree Celsius you can approximately take average. So, stem correction that is required is K times N, which is the length exposed expressed in terms of degrees. Look at here the thermometer is immersed to 0 degree Celsius mark and reads 200 degree Celsius. So, the length is 200 minus 0 is 200. T measured is 200 and T exposed is the temperature at the midpoint which is 35 degree Celsius.

So, if you do the calculation you get 5.57 which is approximately 6. So, corrected temperature is 200 plus 5.57, which is approximately 200 and 6 degree Celsius. In many references the value of K for mercury column is expressed as 0.00016. So, it expect to have 100 degree Celsius, 200 degree Celsius or 300 degree Celsius some references indicate this value.

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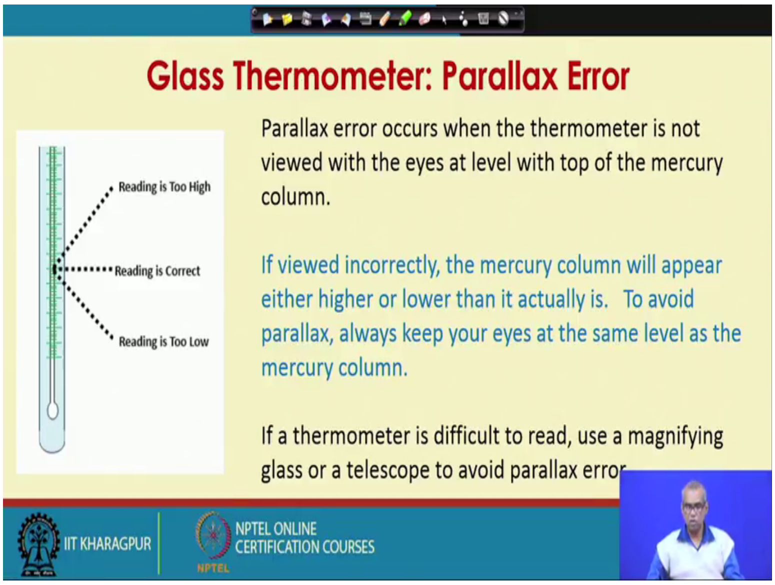

Now, let us talk about parallax error. Parallax error occurs when the thermometer is not viewed with the eyes at the level, with top of the mercury column. So, parallax error occurs when the thermometer is not read correctly. The correct way to read thermometer is that your eyes will be at level with the top of the mercury column. If viewed incorrectly the mercury column will appear either higher or lower than it actually is. To avoid parallax always keep your eyes at the same level as the mercury column. So, if you read like this, your reading will be correct. If you are reading like this you will get a higher reading which will be incorrect.

If you read like this you will get a lower reading, which is again incorrect. So, you must keep your eyes at same level as the mercury column to avoid parallax error. If a thermometer is difficult to read, use a magnifying glass or a telescope or some sort of optical device to avoid parallax error.

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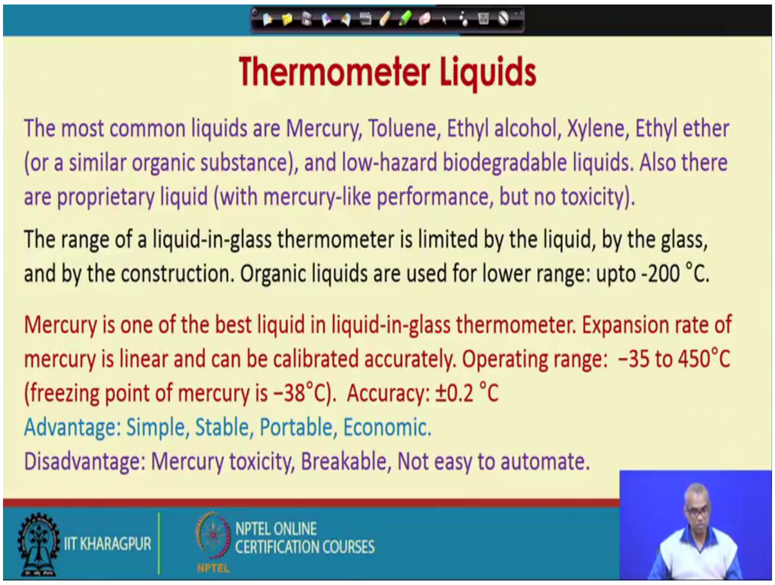

Now, let us talk about what are the different thermometer liquids that can be used in glass thermometers or liquid in glass thermometers. Most common liquid is mercury and alcohol.

However Toluene, Xylene, Ethyl ether or a similar organic substance, and low hazard biodegradable liquids are also used. Also there are proprietary liquids which is mercury like performance, but no toxicity note that mercury has toxicity. The range of a liquid in glass thermometer is limited by the liquid by the glass and by the construction. Organic liquids are used for lower range up to minus 200 degree Celsius. Mercury is one of the best liquid in liquid in glass thermometers; expansion rate of mercury is linear and can be calibrated accurately operating range for mercury in glass thermometer is minus 35 to 450 degree Celsius.

Note that freezing point of mercury is minus 38 degree Celsius, for the lower limit is limited by the freezing point of the mercury. The accuracy of a mercury in glass thermometer is plus minus 0.2 degree Celsius. The advantage of mercury in glass thermometers are it is simple, stable, portable and economic. The disadvantages are mercury toxicity, it is usually breakable because made of glass and also it is not easy to automate.

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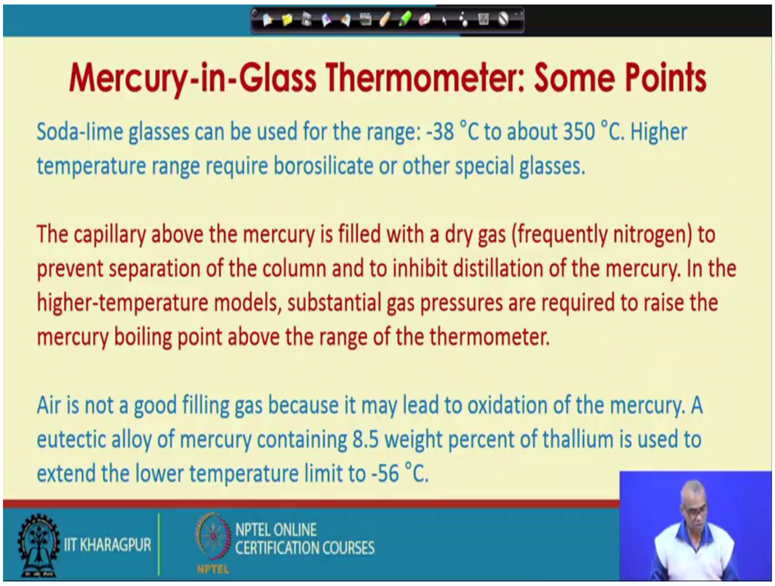

Some more facts about mercury in glass thermometers; soda lime glasses can be used for the range minus 38 degree Celsius to about 350 degree Celsius, higher temperature range require borosilicate or other special glasses.

The capillary above the mercury is filled with a dry gas frequently nitrogen to prevent separation of the column, and to inhibit distillation of the mercury. In the higher temperature models, substantial gas pressures are required to raise the mercury boiling point above the range of the thermometer. Air is not a good filling gas because it may lead to oxidation of the mercury. A eutectic alloy of mercury containing 8.5 percent of thallium is used, to extend the power temperature limit to minus 56 degree Celsius. So, we will stop our discussion on liquid in glass thermometer here.