Welding Processes

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Part 01

Arc ignition mechanisms

So we looked at in the last class the heat transfer in arc, right. So how the heat is conducted, convicted and radiated in an arc, right. It is extremely important to understand these three phenomenal in arc because that determines the action of shielding gas or how the heat is actually transferred from one point to into another point in space as well as in time in an arc from the cathode to anode, ok.

So now to understand that we should look an at all the three aspects like conduction, how conduction is carried out in the arc like we looked at four aspects of conduction is right. So the conduction heat transfer coefficient is made of four components, the first component is the classical heat transfer by conduction and due to the collision of the atoms on molecules, ok so that is a classical heat transfer coefficient we have looked at.

The second is the collision of electrons with these neutral atoms as well as in molecules that is k i k e and then k i which is the diffusion of ionized pair, ok.

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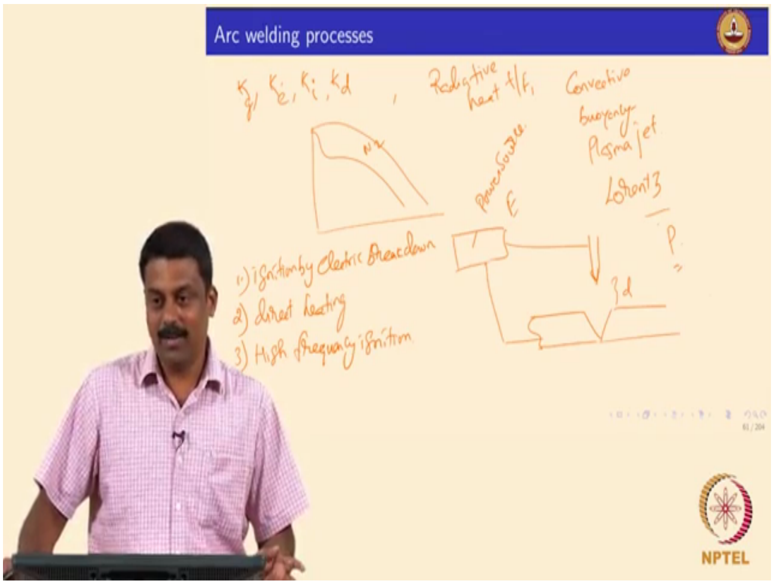

So we have looked at the four, the first is the classical k and then the heat transfer coefficient, ok and then the k i sorry k e which is the collision of electrons with the atoms and the molecules and then k i and the diffusion of ionized pair and then k d is.

Student is answering: Diffusion.

Is a diffusion of dissociated pairs, ok if you use diatomic gas, ok. So k g and then k e, k i, k d all these four together determines the conduction heat transfer in the arc and we have also looked at how the change in from say more atomic gas to diatomic gas how the arc temperature changes is not it, if you use diatomic gas you have a shouldering because the heat is effectively transferred, a distributed and through the volume and due to that and if you look at from the arc center to the arc envelope.

So the you will have a shouldering effect, ok this shouldering effect especially you see in a diatomic gasses because of the dissociation, the heat transfer by the dissociation that mean is that the dissociated gas can also go elsewhere and then combine becomes an the diatomic gas again and during this process the heat is transferred is not it. Similarly we looked at to the examples, so this N 2 for and the N and such a shouldering effect may not be there because the dissociation phenomena is not there, ok.

So this is very important to understand these phenomena because we are going to look at in this class when the selection of shielding gases, so how we can select the shielding gas because based on our heat input and arc the characteristics, ok. So apart from the conductive heat transfer you will also looked at radiative heat transfer, ok. Radiative heat transfer what is the main assumption we made, the main assumption we make here in radiative heat transfer is the radiation coming out of arc is continuous radiation, ok.

So if you assume that it is continuous radiation which is very well valid at higher temperatures like an temperature what it took even arc it more than 10000 kelvin, ok. So the radiation can be continuous spectrum, so in that case that we can use Stephen Boltzmann law to calculate the heat transfer by radiation that is what we have looked at it, right and we also looked at the characteristic typical the spectrum of an arc, ok so the arc looks bluish because the maximum intensity coming out of the arc is in the range of a blue spectrum, ok 400 to 500 nanometers the wavelength of the radiation is not it.

So that is why the arc look bluish because the maximum intensity coming from the wavelengths ranging from 400 to 500 nanometers, is not it. So and then we looked at the convective heat transfer, so how convective heat transfer can also effectively transfer heat from one point to other point in arc and these also very important heat transfer mechanism especially if you use a low density gases for example helium, helium is highly convective gas is not it, helium is known to conduct (con) the transfer heat much more effectively similar in hydrogen as well because the convection is predominant and we have looked at two major effects major the effects it that can cause conductive heat transfer is by buoyancy flow is not it.

In conductive how does buoyancy flow happens? Because of density difference, ok. So at the center of the arc the temperature is high obviously gases the density of gas reduces significantly at higher temperatures so there will be density driven flow which is are known as buoyancy flow, ok and then apart from buoyancy flow we also have a plasma jet formation, is not it.

So plasma jet formation is due to the electromagnetic forces that are generated, so we always have all the charge particles like ions and electrons, so even the two charge particles come close to each other, ok so then what happens then there will be repression repulsive force generated which is known as Laurens force, is not it. So the force is inversely proportional to the distance between two particles, ok.

The smaller distance more the force, so obviously there will be accumulation of charge particles at top of the cathode and obviously if there in accumulation of charges then enormous amount of Laurens force is generated and this loss Laurens force can push or can change the convective flow inside the arc a leading to heat transfer, ok. So that is a convective heat transfer due to the formational plasma jet and plasma jet it is a very significant in welding, in welding arcs because the jet velocity can go as high as to 200 meters per second, it is a huge, ok.

So especially again if use a convective gases and the heat can be effectively transferred and as well as I know the heat the can be distributed much more effectively if use a convective gases. So this all are the basics for selecting shielding gases during welding, ok you cannot just like that go and can weld with organ, you cannot do that or I will just use to carbon dioxide. So you need to understand how these gases effectively generate and transfer heat in arc is not it, so in unless you understand these things correctly it is very difficult for you to choose as welding suitable welding gas.

So in this class we are going to look at how these phenomena would affect the heat transfer and then the nature of a gases what based on the ionization potential as well as density as well as the ionization characteristics or if it is more atomic or diatomic and we can look at each individual gases and then we can arrive at in what gas can be suitable for what application, yes it is clear, ok good.

So we have looked at all these things and then we went and looked at these typical schematic of the welding setup, is not it. So what is important characteristics of an schematic I assured you, what is important factor is not arc itself it is very important, right. The arc which actually generates heat that is the work force for us, ok. So if you say arc then how do we ignite the arc? So first process so we looked at thermionic emission for example thermionic emission emits the electron but then you have a schematic something like this you have a power source, ok and you have a weld interface to be joined and then an electrode, ok it can be consumable or unconsuming, so you connect the electrode and work piece to the power source, ok.

So we keep some distance from the electrode top to the material, so say for example if it is d and then you send an a shielding gas in this setup with a pressure say p would you ignite the arc just like that, you pass a current the electric field in a circuit and the potential difference is generated by itself because you have a circuit but the arc will not be ignited just like that is not it, so either you need to heat up the electrode so high temperature so that you would triggered thermionic emission is not it, but then enormous amount of current electric field intersect.

So now do you ignite the arc, ok so we ignite in the welding arc by three methods, ok the first method is the ignition by electric breakdown, ok the second is it is like thermionic emission by heating by direct heating but direct heating we have knew use a farness are we want to use any external heating source to heat the electrode. We already have current and voltage so we can use a simple dual heating mechanism but again so we modify the heating strategy by dual heating in such a way that we can reach the high very high temperature the top of the electrode.

So we will see how we can end up heating the electrode at localized person at higher temperature so that we can trigger thermionic emission and the third method and the most commonly use method is high frequency ignition, ok. So we have look at all these three, so what are the these three methods how we ignite the arc, ok so the moment you go and start welding in a laboratory or in a work force first thing you do is you switch on the power source, gas bottle open the gas bottle and then you ignite the arc, ok so let us ignite the arc, ok.

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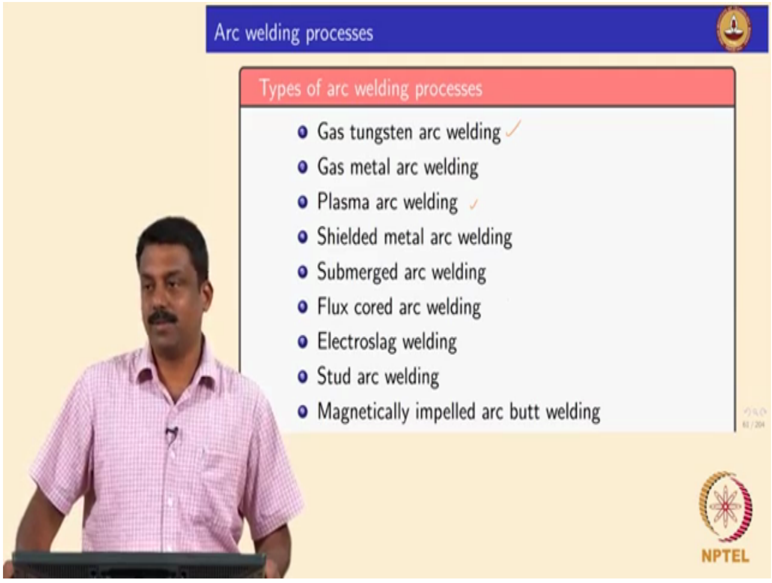

And we use arc for various purposes, right various processes and we modified the setup but the main heat source is still arc, right. How you ignite the arc and what methods you transfer the heat that determine what are welding processes we know in you can invent, ok for example in a if you look at all the arc welding processes so be use arc but the mechanism by which you generate the arc is different as well as the schematic the setup itself you know difference so that we can effectively transfer the arc heat to the work piece, ok for example in gas tungsten arc welding it is a non-consumable welding process we strike an arc by using tungsten electrode, ok or we can also replace the tungsten with a filler and then change the polarity so that a you also melt the electrode and then you deposit the electrode to the welding base material and then you also convert the arc into plasma, ok.

So again the definition of an arc and plasma which you looked at so by doing some strategy we convert the arc into plasma so that we can increase the energy density of an arc, ok so then it becomes an a power beam the plasma beam, ok and then the other welding processes they actually change the strategy of transferring heat from the arc for example shielded metal arc welding or submerged arc welding or flux cored arc welding, electroslag welding and these processes again the heat is arc but how you transfer the heat from the electrode from the electrode to the base material that is different, ok.

So then we have look at in all the processes and then how efficient all these processes, right and then we will move on to the next welding processes, ok.

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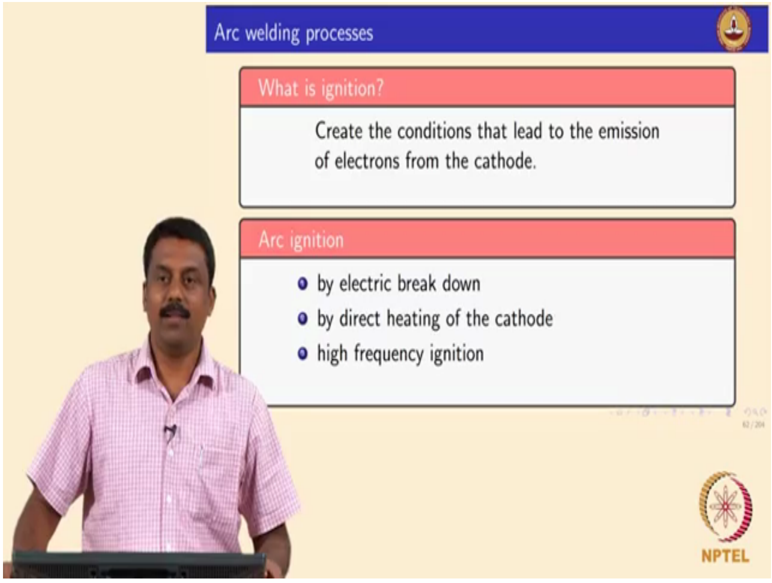

So before that as I explain what is ignition? So ignition is a condition, ok so that lead to emission of electrons from the cathode, right so once you have a sustained emission of electrons and these electrons will further will travel into the gas medium and subsequently they can ionized further leading to a conduction of electric field from one (po) the cathode to anode or anode to cathode, ok.

So the ignition is to create a condition that lead to the emission of electron from the cathode as I said and this can be done by three ways so in all cases ignition means we need to trigger the electron emission from the cathode, so we can either do by electric breakdown or direct heating of the cathode thermionic emission, is not it or we can also do by high frequency ignition and all these three methods are commonly used, ok.

So if you look at a loads in mechanic before yeah doing anything to ignite the arc the mechanic would touch the electrode to the base material is not it, so what does he do.

Student is answering: Saha.

Saha equating because of that what will happen, ok so we will see. So he is using the second method to ignite the arc, ok. So the first method which is actually a bit tricky but it is also used widely is by electric breakdown. Electric breakdown works in the principle that the electrons are always available in the atmosphere, ok so by various methods for example photo electric effect or cosmic radiation, so it will always trigger some electron emissions also in this room he make see some electrons are there but the number of electrons will be much lower, you will have always some electrons are there, ok.

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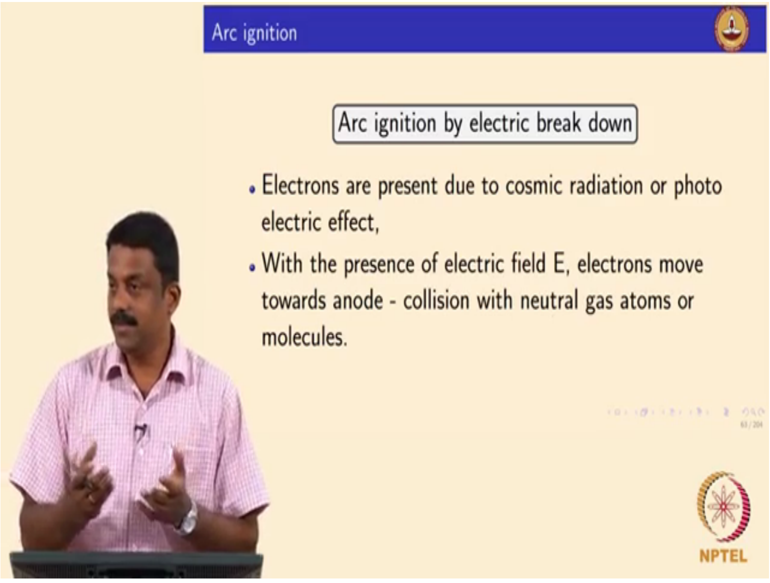

Suppose if you have the electrons in the system by cosmic radiation of photo electric effect and you apply electric field is not it, the power source applies an electric field is not it, so what happens then and because of the application electric field the electrons which are there would start moving around, so electrons would travel to anode and during this process they also collide with the gas items, is not it.

So the electrons what you have in the medium so when you apply electric field these electrons which are created by this cosmic radiation or photo electric effect and these electrons would travels towards anode and during this process they would collide with the gas items, ok. So upon collision if we the keep on collide with the gas items the moment they gain a critical energy, ok.

So what is a critical energy? Critical energy equivalent of the ionization energy of the gas is not it.

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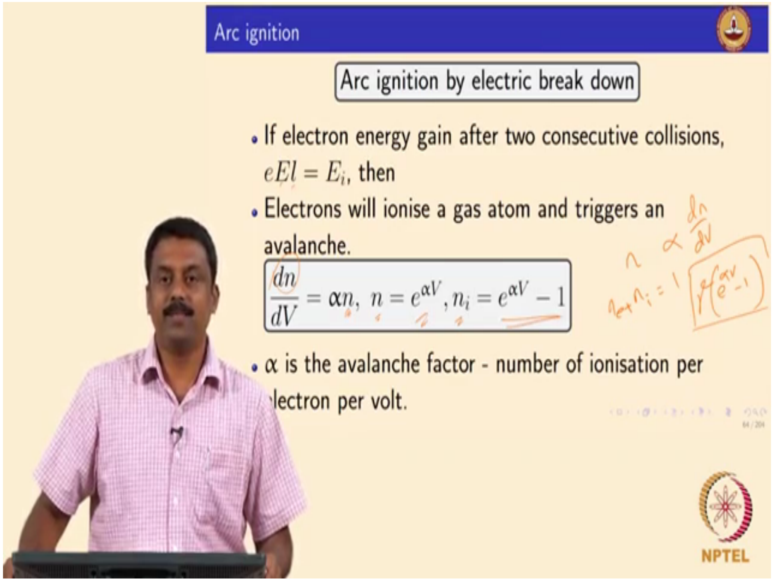

So if the electron that electron which is actually there created by the cosmic radiation or photo electric effect and during this influence of the electric field if they collide with the atoms they gain energy, ok. Suppose if they gain energy equal to the ionization energy of the gas which is there as a medium then it would ionized the gas atoms is not it, it is clear. Say for example l is the electron mean free path, ok and you have a charge of electron which is actually push to the anode by the electric field e so that is the total energy gain the electron gate because of the applying in case of applying the electric field is not it.

A charge of an electron the electric field you apply and the mean free path, right and if these energy equals to ionization energy then you trigger the ionization the electron would trigger ionization, is not it. So now the moment you trigger an ionization then the another electron which is generated by this ionization process would again trigger another ionization, is not it. Look at the energy would be equal to the ionization energy the electron which is coming out because that is the energy gain is energy released, is not it.

So then there will be avalanche of the ionization who take place, so the moment one electron triggers the ionization the other electron which will have an equal energy of ionization energy, ok so because what is consume it is also coming out and then the electron would create subsequent ionization and then the all the electron which is generated would create an avalanche, yes it is clear.

So now once you that phenomena avalanche happens so obviously the number of electrons which are generated by this process, ok so which is nothing but the potential difference between the anode and cathode and then the number of electrons which are actually created, ok. So this total number of electrons available for this action and is nothing but these electrons are pushed towards a potential difference because potential difference which is actually pushing an electron from one end to other end, right is not it so that is a proportional.

So number of electrons which are actually available, ok it is basically that is the proportional to the number of electrons which are actually created over potential difference, yes it is clear yes or no and this proportional constant is known as avalanche factor yes, so basically the number of electrons which are present in the system that is only is going to create an avalanche is not it and this avalanche is proportional to the number of electrons which are pushed over a potential difference, yes it is clear.

So now how do we ignite trigger thermionic emission or emission from the cathode, so now what will happen now so we have ionization triggered by avalanche is not it and if n is a number of electrons which are actually present which is if you solve this equation it will becomes e power alpha v, is not it. So what will be in the volume fraction of ions present it is nothing but 1 minus n is not it or n minus 1 depending on the value of the n, yes or no see is nothing but say number of ions present in the system is so e power alpha v minus 1, so (bot) put together the n e plus n i must be 1 right, volume fraction, mass fraction is not it ok.

So now so this is the number of ions present in the system due to this avalanche reaction, yes. So now what will happen to the ions, ions will obviously go to cathode is not it, so ions would obviously go to cathode, so the moment cathode goes to ions goes to cathode ions would stop bombarding the cathode is not it and during this process when ions bombards the cathode you generate heat is not it yeah, so the when moment ion goes and bombards the cathode you trigger the secondary electrons from the cathode, right it is clear.

Now obviously the moment ions bombards the cathode you heat it up and he triggers thermionic emission and as well as the secondary electron which are generated then what will do you strike an arc, yes it is clear. So the process is a very simple you already have a some electrons due to the cosmic radiation and photo electric effect and these electrons are made to travel to anode by applying an electric field e, ok you applying an electric field e the moment you apply electric field e this electron would start traveling towards anode and during this process they gain energy, energies e small e there is a charge of an electron times the electric field you apply and the mean free path l if that equals to the ionization energy when the that electron which gains the energy equal to ionization energy it collides with an gas atom it would cause an ionization, right it is clear.

So then it will create a avalanche number of electrons would be created and equivalent the 1 minus number of electrons of ions will also be created, ok so now these ions would reach the cathode unfortunately not all ions which are generated reach the cathode is not it some will still be there in the arc column, so one fact about go, ok so that factor if you assume that is gamma, ok so this is number of ions which are actually generate by avalanche, so assume that gamma is the factor which is actually reaching so then number of ions would reach the cathode would be gamma times e power alpha v minus 1 is not it, it just multiplication it is fraction goes, is not it.

So now this defines the electron emission from the cathode because that is what you want, right you need to emit electrons from the cathode that is the ignition by definition, so this many ions would reach the cathode and bombard the cathode so now electrons would be release because of the action of ion bombardment on to the cathode, right it is clear ok.

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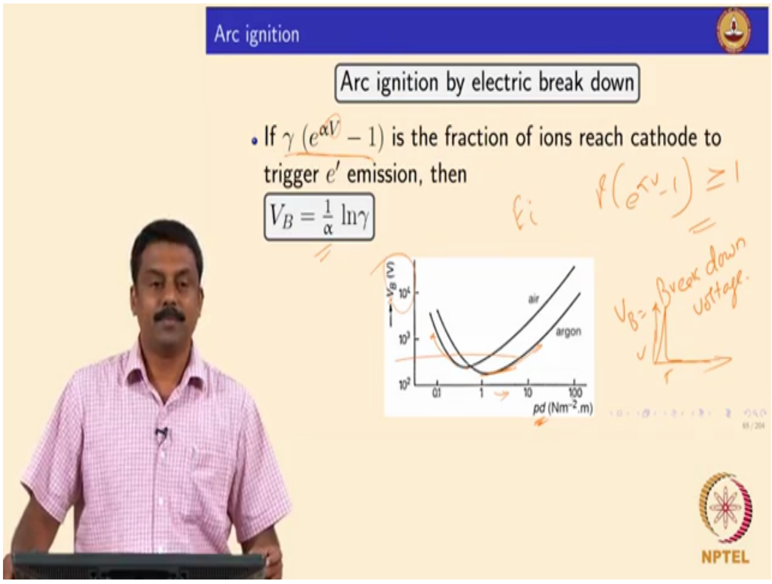

So now we can drive an equation to calculate what is the minimum voltage needed for this action is ultimately that is what we need to ignite the arc. The if you say that this is the fraction of ions reach the cathode the moment ion bombards the cathode what will happen then I will explain you heat up the cathode not only heating up the cathode you will also release secondary electron heating would release the thermionic emission, so once the electrons release the cathode then your definition are ignition can takes place.

If you solve this equation so obviously you would define a critical voltage for the emission of electron from the cathode by the electric breakdown, ok. So basically so this factor alpha v minus 1 should always be greater than 1, so then if that is a case then you would trigger one electron you emit electrons from the cathode, ok. So you solve this equation you will get an a critical voltage for these reaction that is known as breakdown voltage.

So this is the minimum voltage you need to apply to ignite the arc, ok. So suppose if you want to an ignite an arc not by direct touching because touching is in always not always useful, it should be not doing for all the welding processes. So if you want to ignite the arc without a physical contact between the cathode and anode, so you need to apply some breakdown voltage to trigger the ignition, ok that is V B breakdown voltage, ok.

So now we have a problem because I already taught you in the beginning or welding processes always done in extremely low voltages, is not it. The voltage is not more than 30 volts that is why it is make it safe, is not it so we can touch the welding tab even welding is going on, I guess the welding best plate is also part of circuit, suppose if you want to apply very high voltages to ignite the arc then you have a problem is not it, ok.

So now there are some power sources still ignite the arc using the breakdown voltage V B and V B has to be extremely high, ok. So the V B generally it is very high for example the p d if it is one atmosphere pressure then it becomes d is not it, so one atmosphere pressure so this the factor V B is a actually function of the distance which is the distance between the electrode top to the base material, ok and then the pressure, suppose if you increase the d distance the V B can also either increase or decrease similarly pressure as well.

So the relationship if we look at the breakdown voltage as p and d, so there is a minimum at some point, ok. So if you go above this point, ok you need to give very higher breakdown voltage if you go minimum below this point you again you need to give very high voltage, ok. So ideally we tried to enforce this range somewhere over here, so that is why when you doing welding the distance is very critical the arc length or the distance between the electrode top and the base material otherwise you cannot ignite the arc, you need to apply enormous amount of voltage, right so I told you in the previous lectures, previous slides the distance between the cathode anode not more than 10 mm, is not it.

So because of this reason, ok so if the d is higher you need to have very high voltage to strike an arc, ok. Similarly if you are increasing pressure you also need to have a very high the breakdown voltage or if you reduce the pressure you also need to have very high breakdown voltage why is that? So obviously at low pressures, ok the energy gain of electron is very low because they may have a very high very long mean free path.

The collision the probable differ collision is less at low pressure, so then electrons cannot gain energy to trigger the avalanche, is not it also in very high pressures the electron loses energy because of frequent collision, so in both ways the avalanche the probability decreases significantly, ok. So if you keep the distance constant if you are doing it in one low pressure and the one high pressure in the both the cases the voltage will be very high there is a one global minima, ok if you keep the pressure constant again there is only very narrow range at which you can strike an arc, ok.

So the breakdown voltage is a function of the pressure and the distance the d which is a distance between the cathode and anode top, so it is very critical because in most of the cases pressure is constant unless we are doing under water welding, hyperbaric welding where you would encounter the in using the pressures, so then whatever you study whatever you do on a room temperature may not be applicable at under water, ok.

So if you are doing at 100 meters, ok there is only 10 meters increases pressure at one bar, ok so that 100 meters you will have 10 bar of pressure, so whatever you apply you derive an heat input or you derive an a the breakdown voltage so I want to apply say thousand watts to ignite the arc it may not worked down the underwater, ok same with the high pressure chambers for example, ok.

So that is very important so we get the breakdown voltage by calculating the avalanche factors, ok. So the number density of ions and electrons it can be again calculated, ok. So then we know that for given pressure and given distance between cathode and anode so what will be my breakdown voltage? So the power sources are capable of doing it if it is good enough so then what you do not ignite the arc before welding we will have one voltage peak, ok.

So you switch on the power source if you want to ignite the arc by electric breakdown we tell the power source, ok arc ignition by electric breakdown then what we will do before applying the current voltage waveform it will have voltage as time on peak and then you will maintain and this peak is used for arc ignition but doing this peak arc ignition you should not be touch anything, ok then you will be killed instantly because if you look at the if the distance is higher the voltages will be close to 300 to 400, ok so then it is electric shock incident, ok.

So now we if your power source is capable of giving an electric the voltage pulse and then we apply a pulse to trigger the breakdown so once you trigger a breakdown you ignite the arc and then you can maintain the low voltage, yes it is clear and V B is as a function of shielding gas obviously, why it is function of shielding gas? Because of.

Student is answering: Ionization.

Ionization energy, ok so if E i is high so obviously the electrons would gain more energy to ionize, is not it so then obviously the breakdown voltage will also change based on the ionization energy, right it is clear good. So it is a function of shielding gas and the distance between the cathode and anode and the pressure, ok so under isobaric pressure conditions so you can take the pressure out the main functions which determine the breakdown voltage is your shielding gas and then the distance, it is clear.