Fire ignition of NYM cable shield vapor on excessive electric current in multi core cables

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Abstract. People often use electrical appliances exceeds the technical specifications, but if done technically prevention of the manufacture of the cable to prevent the occurrence of fire, the fire risk will be minimized. Under the rules of SNI, heated wires or fed by the overcurrent, to be able to not burn. However, in some occasions, electrical wires burned and turned into a heat source for fires. NYM cable flame characteristics in the event of overload currents, laminar diffusion flame occurs, the process of liquefaction, pyrolysis, diffusion, and combustion clearly seen. NYM cable flame propagation patterns in the incidence of overload start happening at that point reaches ignition temperature, which occurs due to an electric wire heat reaching the melting temperature of copper. Flame propagates in all directions where their fume and oxygen along the cable and around the cable. In certain circumstances, occur splash / explosion of the fuel to evaporate.

1. Introduction
In the home electrical installation system, electrical wiring is one vital component that serves as a conductor of electric current from the power source to the electrical equipment [1]. These cables such as blood vessels in the human body, where the blood vessels when there is a problem of the body will not work properly. The electrical wiring is so, if there is a problem then the channels will potentially disrupt the system of electrical installations [1].

Good electrical installations must use the cable installation according to the standard ISO as NYM cable with PVC insulation. Insulator PVC characteristics to suit the needs of the electric installation of household and qualifying standards as well as some of the advantages of other materials include lighter, mechanical properties better, the nature of loss in electrical smaller dissipation factor smaller and volume resistivity more high [2].

People often use electrical appliances exceeds the technical specifications, but if done technically prevention of the manufacture of the cable to prevent the occurrence of fire, the fire risk will be minimized. Under the rules of SNI, heated wires or fed by the overcurrent, to be able to not burn. But in some cases, even burning electrical wiring and a source of heat for the fire. Until now there has been no study of the characteristics of flame and heat propagation of electrical cable type NYM, resulting in an installation and placement standards and standards may be new material to prevent ignition. To achieve these new standards, it is necessary to study flame characteristic of NYM cable in the event of an overload current, and the pattern of flame propagation NYM cable in the event of an overload that will be done in 2021. Studies characteristics of flame and heat propagation patterns cables NYM the important because it is the initial stage of making products that are safe for the public. Had learned with
flame characteristics of NYM cables, it will be known how a NYM cable caused the fire and the beginning point of the fire. Flame temperature and the occurrence of fire in NYM cable will be referred to as a maximum temperature of wiring and determine the suppression should be done in case of overload. Heat propagation patterns can also be used as a reference to halt the propagation of heat towards the fuel source as fire protection [3].

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7.5\text{N}_2 + 2\text{CH}_2\text{Cl} + \cdots + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O} + 7.5\text{N}_2 + 2\text{Cl} + \text{heat (fire)} \quad [4].
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Reaction above illustrates what happens when the reaction between CH2Cl and a certain amount of air, which is a combustion reaction and produces several gases, including chlorine gas [1,4,5]. Flashes of white was a spontaneous reaction of the combustion gas, which is a result of evaporation CH2Cl PVC, indicating the fire of this reaction. The flame come up when the gas and air reached the ignition temperature of CH2 [5]. Shortly after the initiation of combustion, flame propagation occurs throughout CH2Cl the amount of steam that reacts with air to ultimately decrease the number of reactions shown by its decreasing number of fire occur, thus extinguished by itself [4].

This research was conducted at Fire and Materials Laboratory, Faculty of Engineering, State University of Jakarta. Materials used in this research were Various types of electrical wiring 10A with single, 2 cores and 3 cores.

2. Methods
The method used in this research was a laboratory experiment, which analyze and test the cable given excessive load. With a 10A current cable to be fed 10-160A we will get the data of temperature of ignition, flame propagation time, get NYM cable flame structure and extinguished flame temperature at NYM cable.

![Research scheme.](image)

Description: K = k-type thermocouple

Testing procedures as shown at fig 1 are Start to give current about 160A to cables that tested. Put 5 position of thermocouples to measure the raise of the temperature and put highspeed camera to see the flame. Wait from the start until the cable shield burnt. Record the time, temperature and graphic. Hi-Speed Camera recording process of ignition at the cable sheath at point 1, the form of ignition at the cable sheath at the point 1to 5 and record the temperature rising by acquiring data through computer.
3. Results and discussion

From the test results of SEM in the Faculty of Engineering, we have information that the materials NYM and NYA cable sheath is composed of a main ingredient Carbon as much as 51.48% of the mass and Chlorine as much as 24.23% of the mass. In this mixture, also contained as much as 13.79% oxygen. Carbon components are mixed with a constituent oxygen combustion reaction. In the solid phase, the mixture is very stable, but when it reached the melting point and the point of the vapor, the carbon and oxygen gas to form a compound when it reaches its ignition temperature, it will cause flash [4,6,7].

NYM cable red one core

![Figure 2. decomposition pvc.](image)

As we see in fig.2 This leads to the formation of smaller molecules that allow the polymer to soften and melt, producing a mobile liquid at the temperature of decomposition. Solid decomposition started as soon as reaching vapour phase temperature (250ºC) and releasing some fume to the air. These fume consist of ethyl gasses, hydrochlorine gasses and other impurities. Thermal decomposition of polyvinyl chloride (PVC), which begins to lose molecular HCl (hydrogen chloride) at about 250ºC, leaving behind a char-like residue [3]. These volatile gasses immediately goes up to its bouyant properties that caused by heat. The gas burst since it pressure increased by the rise of decomposition rate. The longer shield exposed to heat, more fume produced by time.

![Figure 3. Flash ignition.](image)

In this phase, pvc decomposes into ethylene chloride (CH₂Cl) is flammable. At temperatures of 455ºC, CH₂Cl gas will undergo self-ignition. At the time reaching ignition temperature 455ºC, then CH2Cl will react with the amount of oxygen, which in this study is limited to the debit 2 liter per minute. In Fig 4 we can say that single and small diameter core quickly heated when 160amps current going through, and this escalate the deformation of shield and yields volatile matter to be burnt. Take very short time to decompose, this single core cable is very dangerous when receiving surge of electric current [8-10].

Figure 4 show us how the temperature rises as soon as the excess current flow through the cables. This cable can hold 10 A of current, and during the surge test of 160A the cable suffer excess heat that applied along the length. T2 show the decomposition temperature 250ºC. Temperature drop happened because the sensor has come off from the surface, not showing real temperature.
Figure 4. Temperature versus time.

Figure 5. (a) decomposition (b) core breakdown.

In the picture above tells the decomposition process of PVC sheath 2 core which has 3 layers of PVC. At current 160 A, the increase in temperature causes a phase change of PVC, characterized by the emergence of smoke which is a gas phase of PVC. In the picture above shows the spark of flame on the cable due to reach the melting point of copper wires. Spark power cable is due to the electrical potential between one end to the other end and become a source of ignition energy [5]. Figure 5b. showed the initial flame built up.

Figure 6. Propagation of Flame (a) ignition (b) propagation (c) flame development.

In the figure 6(a) shows the development of the initial flame. When an electric stepping, electrons will form a band of light with a 2000K temperature combustion reaction gas starting CH2Cl. The growth of the flame, starting from the gas to be around early ignition source. In figure 6 (b) shown that the fire to grow along the surface of the sheathing, because there's largest fuel concentration near the surface of the cable which then moves up to continue its combustion reaction. Last picture in figure 6 (c) shows that the flame has been fully developed, which is moving toward the source of fuel. This diffusion combustion process occurs because the amount of fuel vapor which moves up provided a constant which
then diffuses oxygen laminar. Flame length is determined by the amount of fuel that moves up and react with oxygen. Fig 8 shows how the temperature built up since the first second until the flame ignited [5].

![Temperature graph of 2 cores cable](image)

**Figure 7.** Temperature graph of 2 cores cable.

Figure 7 tells us how temperature built during the time, it raised a while since the diameter of shield quite thick and transmitted to outer diameter, so the temperature spreaded along the thick diameter and take time to reach decomposition temperature. The peak of T1 (490°C) happened because the flame impinged the thermocouple. These temperatures.

NYM 3 core cable

![The process of changing a solid phase to a liquid-gas](image)

**Figure 8.** The process of changing a solid phase to a liquid-gas, (a) decomposition (b) ignition (c) propagation.

In the figure 8 (a) shows the process of changing the cable sheath into the liquid-gas. Gas is a source of ignition of fuel in the reaction. Like the previous process, the amount of PVC depending on the hot steam is formed, the hot sheath, the more the number of pvc which turns into a gas [3,4,7]. Next picture (b) shows that the spontaneous reaction occurs at about the veil, which is a regional concentration of fuel with oxygen diffuses. This spontaneous ignition caused by the sparks from the cable core rupture copper reaches its melting point, so that the initiator of the combustion reaction. The figures show the reaction stems from the cable core, then spread out in accordance with the area that has a mix of pvc vapor and oxygen. Gradual flame propagation occurs always outwardly from the activation energy source [8,11,12] The fire continues to spread throughout the cable sheath, taking out all the mixture of air and fuel are available. In areas far above the cable, flame propagation occurs in accordance with the direction of the flow of gas and air diffusion that tends towards the top for steam pvc volatile. Next picture (c) shows the combustion reaction continues until all the fumes burned out. The flames are
formed depending on the turbulence of the fuel vapors that occur. The greater the turbulence, the better diffusion of air and fuel. Turbulence occurs due to the volatility of fuel vapor, the hotter the lighter steam and the greater its turbulence [3,8].

4. Conclusion
In all three trials for each type of NYM cables, ranging from single core to multi-core, it was found that the overall cable sheath does not have a heat-resistant coating. PVC material which become constituent wires, can turn into the gas phase at temperatures of 280 degrees Celsius. At the time into a gas, this PVC will be a source of combustible fuel. Especially when the temperature reaches the ignition or spark. This study found PVC due to accumulation of gas ignition temperature, causing a short blast on pvc gas concentration at the top of the apparatus. In some experiments, ignition occurs due to the copper core spark reaches its melting temperature, so that it becomes a source of ignition. Excess load current into a latent danger of electrical installations. This is supported by the electric cable sheathing composition pvc volatile phase into a gas, the cable core which has a small cross section and reaches its melting temperature, so that it becomes a source of ignition. In the event of a power surge that is very large and short, then fires will easily occur in a short time and scale.

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