Fire Investigation Essay:

Dangers and Precautions used in Welding

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**HOT WORK PERMIT (ATTACHED)**
Dangers and precautions used in welding

Abstract
The main types of welding are oxyacetylene gas welding and arc welding. Both involve the joining of metals at high temperatures. Cutting metals using these techniques involves the separating of metals at high temperatures. Welding and cutting pose a serious fire hazard as fragments of metal at high temperature are produced and if these hot metal fragments come into contact with a combustible material they may act as an ignition source and start a fire. Cutting metals is much more of a fire hazard than welding, because during cutting operations many more sparks of hot metal shower from the work, providing a potential ignition source for a fire.

There are many precautions that should be taken when welding or cutting to reduce the risk of fire and/or minimise the amount of damage caused by the fire. Listed below are what I consider the ten most important precautions to take when welding/cutting in order to reduce the fire hazard:

1. Have firewatchers present. These are trained people who watch out for fires and know what to do when a fire occurs.
2. Minimise availability of combustible materials. This may involve removing combustible materials from the area, or shielding them from sparks with metal shields and/or fire-resistant tarps.
3. Suspend a fire-resistant tarp beneath the work if necessary, to catch any hot/molten metal that may fall through.
4. Have fire fighting equipment (including appropriate extinguishers) available for immediate use.
5. If welding or cutting is to occur in a ‘hazardous situation’, obtain a hot work permit to ensure adequate precautions have been taken.
6. Workers and supervisors should be trained in safe welding practices, and the use of fire-fighting equipment.
7. Wear fire resistant clothing. A flame resistant apron (usually leather) and spats to prevent molten metal going down the welder’s boots. No cuffs or open pockets, and no flammable material (eg matches) in pockets.
8. When oxyacetylene gas welding or cutting, never leave a lit torch around when it is not in the welder’s hand.
9. When oxyacetylene gas welding or cutting, never point the torch at cylinders, regulators, hose, or anything else that may be damaged and cause a fire or explosion.
10. Before arc welding or cutting, ground the electrical equipment to reduce the risk of the transformer causing a fire by triggering the electrical supply circuit protection.

Taking the above precautions, and others, may help to reduce the risk of a fire caused by welding/cutting, and may reduce the amount of damage such fires cause every year.
Introduction
Welding is a general term for various processes used to join metal parts by producing a coalescence, called a weld, at a joint. This is usually done by applying heat and energy whilst bringing the pieces of metal together. This essay will refer to the fire dangers and precautions of not only welding, but also cutting metals, which is similar to welding except that the metals are separated instead of joined. As welding (and cutting) involves very high temperatures (up to 5500 degrees C), there is always the risk of fire, especially when combustible materials are around. These fires cause millions of dollars damage each year and the loss of life. Therefore it is important to recognise and understand the dangers and risks involved when welding, and to implement safe practices to reduce these risks.

To understand why welding/cutting pose such a dangerous fire hazard, this essay will firstly discuss the most common welding practices. The extent of the danger will then be discussed. The ways in which welding/cutting operations cause fires is described, which then leads into a comprehensive discussion of precautions and safety practices that should be implemented when welding to reduce the risk of fire, or at least minimise the amount of damage caused. The conclusion will summarise both the fire dangers of welding, and the most important safety practices to reduce these dangers.

Background
Welding
Welding has many applications, both domestically and industrially. Some welded products include ships, aircraft, automobiles, electric and electronic parts, and in building and construction work.

Although over 50 welding processes are used today, the most common ones are gas welding and arc welding.

Gas Welding
Oxyacetylene welding (a form of gas welding) is the oldest type of welding and was developed at the beginning of the twentieth century. Oxygen and acetylene are fed into a torch and ignited to produce a burning gas with a temperature of around 3000 degrees C.
The welder has good control of the weld, as they hold the oxyacetylene torch in one hand and a rod of filler metal in the other. The heat of the torch causes the filler metal to gradually fuse with the joint.

Arc Welding
Arc welding is the most widely used form of welding as it is fast and produces strong welds. Arc welding is often used for commercial work.
An electric welding machine is used which consists of an electric circuit that produces a high current/low voltage output. The parts to be welded are connected to one terminal of the circuit, and an electrode is connected to the other. The electrode is a rod of filler metal and this metal is usually about the same composition as the metal being worked on.
When the electrode is touched to the workpiece and slightly withdrawn, an arc (like a tiny lightning bolt) is produced. This happens because the two ends of the electric
circuit are close enough for the current to jump the gap. The temperature of the arc is about 5500 degrees C which will melt most metals. As the arc is drawn along the joint, the tip of the electrode melts together with the electrode. The most common form of arc welding is manual shielded metal arc welding. The electrode is coated with chemicals which partly turn into gas and partly melt in the arc. The melted chemicals are called a slag which forms a protective blanket over the new weld. The gas acts as a shield by keeping out the atmosphere.

**Cutting**

Gas and arc welding equipment can also be used for cutting metals. In fact, oxyacetylene gas and arc cutting cause more welding environment fires than any other means. Oxyacetylene gas cutting is similar to oxyacetylene welding, except that the blowpipe is fitted with a cutting attachment and work is done at a greater pressure. The effect is quite dramatic as sparks of hot metal shower from the work. These sparks provide a potential ignition source for a fire. Arc cutting is similar to arc welding, except that special electrodes are used and the molten metal is either oxidised or blown away. The electrodes are coated with an insulating material which does not conduct electricity, and hence they are nonconsumable, unlike in arc welding where the electrodes are used up.

**How the fire may occur**

Generally, as welding (and cutting) involves such high temperatures, fires occur when hot metal (sparks) comes into contact with some combustible material. To avoid confusion, it should be noted that in welding terminology, a ‘spark’ refers to the luminous particle that can be formed when an arc melts metal. Quite unlike the usual meaning of the word ‘spark’, which is a high voltage discharge. Cutting of metals (arc and gas) poses more of a fire hazard than does welding. This is hardly surprising considering the relatively large amount of sparks produced as the metal is cut as opposed to when it is welded. As the metal is cut, (using welding techniques), sparks and hot, molten metal fly off in all directions. Furthermore, the sparks from cutting may travel some distance, and as they are small, may drop down through small holes causing a fire to start. In arc welding or cutting, the temperature in an arc path may also be a competent ignition source. In fact, the power in a welding arc is enough to ignite nearly any combustible material. This very rarely happens however, as the arcing is so brief and localised that solid fuels such as wood or plastic cannot be ignited. The arc may cause the fire however, if it comes in contact with fuels with a high surface area to mass ratio, such as cotton batting and tissue paper, or combustible gases and vapours.
Precautions and Safety Procedures

There are many precautions which should be taken and safety procedures to be followed to reduce the risk of fire or to minimise the amount of damage in the event that a fire does occur. Some of these are general to all cutting/welding operations, whilst others are specific to a certain type of welding, or to specific circumstances of the project.

Firewatchers

Firewatchers are people who watch for fires in exposed areas. If a fire does occur, the firewatcher will extinguish the fire or, if this is not possible, sound the alarm. It is important therefore that the firewatcher is well aware of the location of all extinguishing equipment, and is properly trained to use it. Firewatchers should keep watch for fires not only whilst the welding is taking place, but at least half-hour after the completion of the welding operations. This is so they

Above is a picture of a welder cutting- note the shower of sparks produced.
can detect and extinguish smouldering fires. For larger jobs, several firewatchers may be required to keep watch properly. The work area should also be checked at least 4 hours after completion of the work, in case of smouldering fires. However the same firewatcher needn’t do this.

**The Welding Environment**

Ideally, welding should be carried out in specially designated areas of a workshop. To reduce any fire hazard, these areas should have:

- Concrete floors
- Fire extinguishers
- Arc filter screens
- Protective drapes or curtains
- Adequate ventilation

Also, whenever any welding/cutting operation is carried out, the area should be free from any combustible material that may fuel a fire. When the work cannot be done in a specially designed workshop, other precautions must be taken to minimise the fire risk.

If the floors or roofs are combustible, they should be wet down with damp sand and/or covered with metal shields or fire-resistant tarps. The walls should also be protected if they are combustible. Also, any openings in the walls or floor should be covered with non-combustible shields to prevent hot metal travelling through these openings. If this is not possible, for example when the opening is too large, and the opening exposes flammable material in nearby areas, then the opening should be guarded by firewatchers. Sometimes it is necessary to suspend fire-resistant tarps beneath the work area to catch any hot/molten metal that may fall through. This is especially important when the work is being conducted above an area which contains combustible materials. A case when this was necessary but was not adhered to is the July 1994 Boston Harbor Tunnel fire. Welders were cutting bolts from a bearing housing and these hot bolts and nuts then fell into the shaft. On coming in contact with the conveyor belt, the hot metal bits then started a fire which could have been avoided had a fire resistant tarp been suspended beneath the work area.

Another example is the April 1991 fire in the US embassy in Moscow. The fire was cause by hot sparks dropping down from welding that was being done in the elevator shaft. Had a fire resistant tarp been suspended beneath the welders, this fire too, could have been avoided.

**Fighting the Fire**

Even after precautions are taken to reduce the risk of a fire occurring, a fire may still occur. It is important to be prepared in case this does happen. Before commencing the work, it is important to establish that the appropriate fire fighting equipment is available and ready for use, and that staff are properly trained in using such equipment.

**Fire protection systems**

Depending on the nature of the work, various types of fire fighting systems should be present. Before any work commences, it should be established that these systems are functioning, and will continue to function during and after hot work operations. The Australian standard for welding safety AS1674.1-1990 states that in regard to fire protection “suitable equipment and extinguishing agents appropriate to the risk
shall be provided and available for immediate use”. An example of a result of breaching this standard is the August 1993 fire at Sydney international airport, in which a welder was unable to extinguish a fire caused by his work because the water had been turned off for previous work on water service lines. Had the AS1674.1-1990 standards been followed, the welder may have been able to extinguish this fire before it got out of control.

To establish that fire protection systems are not malfunctioning various checks should be carried out. For example control valves for fixed protection systems should be fully opened.

An appropriate fire extinguisher should be within 10 metres of the work area, in accordance with the Australian standards for welding safety AS1674.1-1990. This extinguisher should comply with the relevant Australian standard and should be adequately maintained.

As well as a fire extinguisher, a bucket of dry sand and a pair of water buckets should be at hand. These are used in addition to other fire fighting equipment to fight certain types of fires. Sand is effective in smothering fires of flammable liquids such as oil, petrol, paint, etc (class 6 fires). The buckets of water should be used only to fight fires in which wood, paper, clothing and similar materials are burning (class A fires).

**Hot work permit system**

In Australia, a hot work permit is required before any welding or cutting is carried out in a ‘hazardous situation’.

It is the responsibility of property and plant management to oversee the permit-issuance system. The Responsible Officer issues the hot work permit after they are satisfied that certain precautions have been followed and the hot work may proceed safely.

The hot work permit covers aspects of the work such as the times the work may be carried out, the equipment to be used and the precautions which have been taken. A typical form for a hot work permit is attached to the end of this essay.

Once work has been approved as safe, the hot work permit is filled out and signed by the Responsible Officer. The permit is then posted at the worksite. It is signed again at the completion of the work, and filed for documentation.

**Combustible and flammable materials**

The Australian standards on welding safety AS1674.1-1990 states that any flammable or combustible material within a 15 metre radius of the welding, should
be identified and controlled before performing the welding. It is preferable to remove such materials to a safe distance away from the work area, but if this is not possible, then they should be adequately covered by metal shields or fire resistant tarps. Thought should also be given to flammable/explosive vapours. If it is possible that such vapours are present, the area should be cleaned and purged and the air sampled to ensure that combustible vapours are less than 10% of lower explosive limit (LEL).

Substances such as paint, oil, cleaning chemicals and other possible combustibles should be kept in cabinets made from steel to prevent them fuelling a possible fire.

**Welding on containers**

Containers of flammable materials should never be welded or cut with a torch, even if the container has been completely empty and sitting empty for a long time, as vapours and flammable materials can still permeate the metal. An example of what can occur when such containers are welded on occurred in the early 1990s when a welder in the USA was cutting 55-gallon oil drums in half. As his cutting torch pierced the metal of one of these drums, the drum exploded and the welder was blown through the shop’s roof, 50-feet up in the air.

Vapours from flammable liquids are explosive and should be handled with extreme care. Vapours from non-flammable liquids can also be explosive under certain conditions.

If welding is to be carried out on vessels of flammable or combustible materials, the vessel should be drained, cleaned, purged and tested for flammable vapours before the work begins. The transfer piping should also be drained, purged and blanked. As a rule, only welders who are properly trained to do so should weld or cut a container that has held flammable or hazardous materials.

**Whose responsibility is fire safety in welding?**

To reduce the risk and minimise the damage of fire, personnel involved in welding/cutting operations should cooperate in taking adequate precautions and pursuing safe practices. The general guidelines of responsibilities are as follows:

- **Management** - arrange hot work permit and ensure that adequate firefighting equipment is available (for immediate use). Ensure that supervisors are correctly trained.

- **Supervisors** - verify that safety equipment is present and properly maintained, ensure workers are correctly trained on safety aspects of their work, especially what to do in the case of a fire. Ensure the working environment is fire-safe, especially the removal of flammable materials, arrange firewatchers.

- **Workers** - follow safe practices, report unsafe conditions, mark hot metal and stop work if conditions change and become unsafe.
Training
Workers and supervisors should be properly trained in the correct use of firefighting equipment such as extinguishers and blankets. To minimize injuries/loss of life, they should also be shown where the fire exits are, and how to use them in an emergency. A good method of doing this is to have periodic fire drills. To reduce fire hazards, workers and supervisors should also be made aware what equipment should be shut down before leaving the work area.

Oxyacetylene gas welding
There are some special precautions which should be taken when welding or cutting with oxyacetylene gas to reduce the risk of fire. Cylinders of acetylene, oxygen and other high-pressure gases should be stored upright in an approved area (vented to atmosphere with flameproof switches and lights), with their safety caps in place. Acetylene gas should not come into direct contact with copper or alloys >70% copper, since copper acetylide, an explosive compound is formed. Therefore, acetylene piped from the manifold should be conveyed in iron or steel pipes. When the welding work is finished and the flame has been extinguished, the system should be emptied of all gases from the cylinder outlet to torch tip. The torch should never be pointed at the cylinders, regulators, hose, or anything else that may be damaged and cause a fire or explosion. If the torch is lit, it should be in the welder's hand only. A lit torch should never be hung up or placed down on the bench or workpiece. Check valves and flashback arrestors should be installed in all oxyacetylene gas welding and cutting outfits. Be sure that no combustible material is in the area where the torch is to be lighted. Light the torch with a spark lighter.

A backfire is when the flame flashes back up the nozzle and is arrested at the mixer or injector in the blowpipe body. Backfires may be caused by using a dirty tip, an overheated tip, or working at insufficient pressure. If this occurs, the blowpipe valves should be turned off. The cylinder valves should be closed and the equipment checked before welding recommences. Overheated tips or nozzles may be cooled in a bucket of water. A flashback is when the flame burns back into the tip, torch, hose, or regulator. It means that there is something radically wrong with the equipment which should be corrected before being used again. If a flashback occurs, the oxygen torch valve should be turned off quickly and then the fuel gas torch valve. Next the oxygen cylinder and fuel gas cylinder regulators should be closed. Acetylene gas itself, although bottled at relatively low pressure, is highly explosive. If it leaks into a confined space, nothing will happen until there is a spark or flame to ignite it. Then it may explode similarly to a stick of dynamite.

Arc welding
As arc welding involves electricity and high currents, these may create special fire and safety hazards. Prior to the commencement of a welding project, it is important to ground all electrical equipment. This is to reduce the risk of electrical shock or the transformer causing an electrical fire by triggering the electrical supply circuit protection.
Clothing

When welding, special protective clothing should be worn to protect the welder. This essay will not endeavor to describe such outfits, but will only look at clothing from a fire safety perspective. Clothing and accessories should be fire resistant. Leather is the best choice, but wool is also suitable. The clothing should not contain cuffs or open pockets, as these might collect sparks or hot metal. Flammable material (e.g. matches) should not be carried in the pockets of clothing. With regard to fire safety, the two relevant items of clothing are a flame-resistant apron, usually made of leather, and spats, which prevent molten metal going down the welders boots.

A = flame resistant apron
E = spats

Conclusion

Welding and cutting metals by various methods especially oxyacetylene gas and arc welding produces very hot fragments of metal, or ‘sparks’ and thus pose a dangerous fire hazard. Every year much damage is caused by these types of fires, especially fires caused by cutting, and often these fires could have been prevented, or the amount of damage reduced, by taking precautions and undertaking fire-safe welding practices.
References

Books

Journals

Other Publications
APPENDIX C
TYPICAL FORM FOR A HOT WORK PERMIT
(This Appendix does not form an integral part of this Standard.)

1. Site location _____________________________ Date __________ Permit No. __________

2. What hot work is covered by this permit? ___________________________

3. Where is the hot work to be carried out? ___________________________

4. What equipment is to be used? ___________________________

5. List the fire fighting equipment to be laid out at the worksite ___________________________

6. The following checks have been made: (Note: All questions are to be answered and initialled by the issuing Responsible Officer).
   6.1 Have drains, pits and depressions been checked, isolated and sealed? __________
   6.2 Have combustible materials been removed from the work area or made safe? __________
   6.3 Have tanks, valves, vents and pipelines been blanked off or effectively isolated? __________
   6.4 Is ventilation adequate? __________
   6.5 Are spark/flash screens in place? __________
   6.6 Have leaks from valve/pump glands, flanges, etc., been controlled? __________
   6.7 Have pressure relief valves been vented to safe areas? __________
   6.8 Has contaminated ground been covered? __________
   6.9 Has the fire equipment checked and laid out? __________
   6.10 Is the fire pump or fire brigade on standby? __________
   6.11 Is a firewatch required and organized? __________
   6.12 Is the wind direction satisfactory for hotwork to be done? __________
   6.13 Has product movement been stopped in the area of hotwork? __________
   6.14 Has the site of hotwork been isolated/roped off? __________
   6.15 GAS TESTING:
      Equipment make/model __________________________
      Serial no __________________________
      Date of last equip check __________________________
      Date of test __________________________
      Time of test __________________________
      Results of tests __________________________
      % L.E.L. __________________________
      Is hotwork safe to proceed? __________________________
      Initials of tester __________________________

7. The following conditions/precautions being observed.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8. This Permit is valid from ________ am/pm on __/__/___ to ________ am/pm on __/__/___

9. Name of contractor performing the work __________________________ Order or contract no. __________

10. Permit received by: __________________________ 11. Person in charge of location __________________________ 12. Responsible Officer __________________________
    (print name) __________________________ (print name) __________________________ (print name) __________________________
    (signature) __________________________ (signature) __________________________ (signature) __________________________

Return of permit: This permit was returned/cancelled by: __________________________
    to: __________________________
    at am/pm ________ __/__/___

The worksite has been inspected by me at the expiry/cancellation of this HOTWORK PERMIT and declared SAFE for normal operations to resume.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

R.O. __________________________
(print name) __________________________
(signature) __________________________

THIS HOTWORK PERMIT MUST BE DISPLAYED PROMINENTLY ON THE WORKSITE

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