

STEM bulletin

supporting STEM for all Local Authorities through advice, ideas and inspiration

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Resistance spot welding

Resistance spot welding, usually referred to as spot welding, is a process that is widely used for joining thin sheet metal. This type of welding is commonly used in technology departments due to its fairly straight forward use and quick results.

However, there are some tricky issues in the initial setting up of the spot welding equipment (see Figure 1) and as a result we have put together this quick and handy guide.

The process of resistance spot welding is undertaken by overlapping sheet metal and clamping it between copper electrodes, which have reduced diameter tips to produce welds that are usually between 1.6 mm and 12.5 mm in diameter. A large current is then passed through the work for a pre-set time, the higher electrical resistance causes local heating, sufficient to melt the metal. The pressure from the electrodes unites the molten metal once cool. This combination of heat, pressure and time is how each weld is produced. This is usually repeated multiple times along the length of the metal.

Pressure

The amount of pressure that is applied to the weld is an important factor in producing quality welds. If too little pressure is applied, the joining area will be small and weak.

If too much pressure is applied, then cracking can occur in the weld because the correct electrode tip angle will not be maintained.

High pressure can also cause thinning of the metal and cause a weakness. The depth of the depression on the sheet surfaces caused by the welding electrodes should never exceed 25 percent of the sheet metal thickness.

The primary purpose of the pressure is to hold the parts to be welded in close contact at the joint. This action assures consistent electrical resistance and conductivity at the point of the weld. The electrode tips should NOT be used to pull the workpieces together. Spot welding machines are not designed as an electrical “C” clamp. The parts to be welded should be in close contact before any pressure is applied. Investigations have shown that high pressures exerted on the weld joint decreases the resistance at the point of contact between the electrode tip and the workpiece surface. The greater the pressure the lower the resistance factor.



Figure 1 - Typical spot welder.

Proper pressures, with close contact of the electrode tip and the base metal, will tend to conduct heat away from the weld. Higher currents are necessary with greater pressures and, conversely, lower pressures require less current from the resistance spot welding machine. The pressure is usually adjusted by turning the thumbscrew, situated directly behind the electrode arms (see Figure 2). A range of pressure forces for different circumstances is usually also located somewhere on the transformer body (see Figure 3)

Weld timer

The weld timer controls the amount of time the current flows into the welding transformer. In most cases several thousand amperes are used in making the spot weld. Such amperage values, flowing through a relatively high resistance, will create a lot of heat in a short time. To make good resistance spot welds, it is necessary to have close control of the time the current is flowing.

Most resistance spot welds are made in very short time periods. Since alternating current is normally used for the welding process, procedures may be based on a 50-cycle (UK mains frequency, fifty cycles = 1 second). >>

Thumbscrew pressure adjustment



Figure 2 - Weld pressure adjustment.

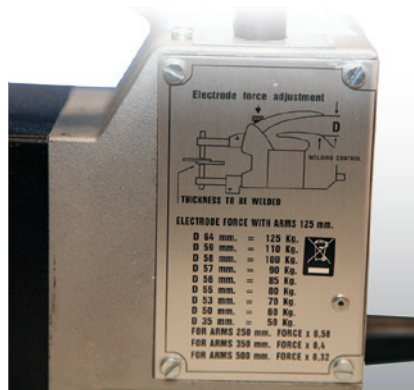


Figure 3 - Weld pressure forces.

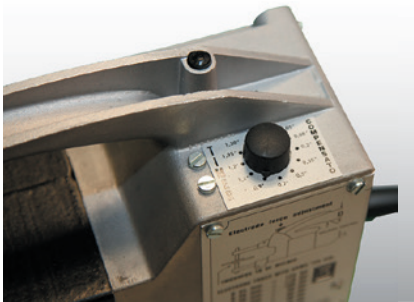


Figure 4 - Timer control.

Control of time is important in that if the time element is too long, the base metal in the joint may exceed well beyond its melting point. This could cause faulty welds due to gas porosity. There is also the possibility of expulsion of molten metal from the weld joint, which could decrease the cross section of the joint weakening the weld. Shorter weld times also decrease the possibility of excessive heat transfer in the base metal. Distortion of the welded parts is minimized, and the heat affected zone around the weld nugget is substantially smaller.

Generally, the time the current flows is control by setting the black control knob at the rear of the transformer (see Figure 4). The pointer can be turned to match up with the required time. Information on how long weld times should be, are usually found on a table at the side of the welder (see Figure 5).



Figure 8 - Electrode cutter fixed into drill chuck.

WELDING EXAMPLE						
THICKNESS mm.	TIME	Ø	FORCE	ARMS mm.	SPOT	
0,8+0,8	0,15"	4mm.	80 Kg.	55mm.	125	300
1+1	0,35"	4,5mm.	90 Kg.	57mm.	125	240
1,5+1,5	0,8"	5mm.	100 Kg.	58mm.	125	120
2+2	1,25"	6mm.	125 Kg.	64mm.	125	60
0,8+0,8	0,2"	4mm.	50 Kg.	65mm.	250	400
1,5+1,5	1,2"	5mm.	65 Kg.	70mm.	250	120
1+1	0,6"	4,5mm.	45 Kg.	68mm.	350	300
1+1	1"	4,5mm.	38 Kg.	69mm.	500	300

SPOTMATIC

F CLASS ITEM IN N:

2 40 VOLT 50 Hz 17/30

2 KVA at 50% - CONVENTIONAL POWER

12,5 KVA MAX WELDING POWER

7200 Amps. SHORT CIRCUIT CURRENT

125 mm ELECTRODES FORCE L=125 mm.

THIS APPLIANCE MUST BE EARTHED

Figure 5 - Welding times.

Electrode angles

As the spot welder is used the electrode tips, which are manufactured from chromium/copper alloy, will eventually wear and require refacing. Obtaining the correct angle (an included angle of 120°) on the electrode is important in achieving good weld penetration and thus weld quality (see Figure 6).

Angle cutting

There are a number of methods of achieving/maintaining this angle. The easiest and most convenient way is to purchase a purpose made tool as shown in Figure 7.

This small tool/cutter is used by fitting it into the chuck of a small power drill. It is then inserted over the electrode and spun at a slow speed. As the electrode must fit inside the profile cutter before any metal is cut it results in an accurate angle being achieved.

Another method of refacing the electrode tips is with the use of a specially adapted file, but this method requires some skill. You must hold the file at the correct level and angle, working back and forth around the tip's circumference, alternatively an ordinary hand file will produce similar results, if used with care. Whichever method is employed an included angle of 120° must be achieved.



Figure 6 - Electrode angle.



Figure 7 - Electrode cutting tool.

Material preparation

To achieve good quality welds, it is essential that the metal to be welded is cleaned to a bare, shiny surface. Electrical current will take the shortest route of least resistance, therefore it is important that good flow paths are created by sanding/cleaning the metal with an abrasive such as emery cloth or a wire brush. One of the main difficulties with this form of welding is the difficulty in protecting the metal between the joint from corrosion once they have been welded. One method of overcoming this problem is to use products such as weld-through primer. These are painted on before the metal is joined together.

Weld spacing

The distance between each spot weld is of paramount importance if consistently good quality welds are to be expected. It should be not less than 25 mm. Spot welds produced at intervals closer than this are likely to be affected by a condition known as shunt, which can weaken then weld considerably (see Figure 9). >>

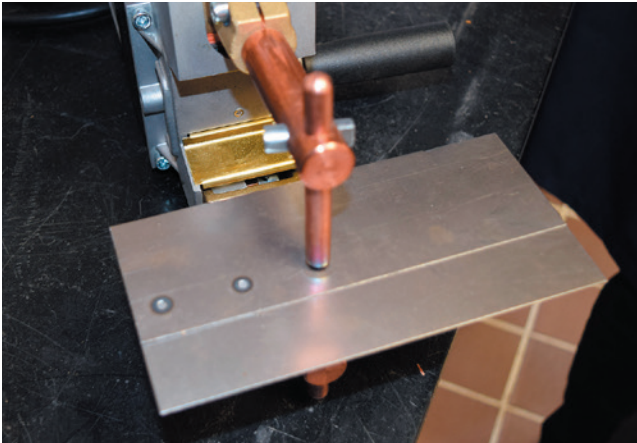


Figure 9 - Each weld should be spaced no less than 25 mm apart.



Figure 10 - Testing weld quality.

Weld quality test

The only way to ensure a series of welds is likely to be of high quality is to carry out a peel test. This should always be done with new equipment or in unknown situations. For example, to obtain the same degree of strength when welding two pieces of 0.9 mm (20 swg) metal, as opposed to three, a different time setting is required. When carrying out the test you will need a number of metal offcuts to use as test pieces. With the metal being “peeled” apart, a hole left in one plate would indicate a good quality weld.

Weld defects/remedies

Compared to other forms of welding, few defects can be expected with resistance spot welding. However, faults that commonly occur are

Defect	Remedies
Blow-holes Overheating Lack of fusion	Lack of pressure between electrodes and workpiece, causing too much resistance on the outer surface of parent metals rather than between them where the weld nugget should be formed.
Overheating	Time setting for each weld too long.
Incomplete fusion	Time setting for each weld is too short.
Metal deformed or rough	Poor tip shape, incorrect angle, tips out of alignment, or electrode holder pivot points badly worn.
Metal falls apart	Insufficient weld time, or pressure, or dirty material, therefore no contact.

due to overheating, blowing holes, incomplete fusion and deformed metal surface. Most of these common faults can be attributed to improper adjustment

of the spot welder. The following table specifically refers to faults/remedies when welding low carbon steel, though it can provide useful reference of other applications. <<

What is creativity?

We are delighted to confirm that Dennis Sherwood from Silver Bullet [1] will be leading a 2-day residential workshop (27-28 May 2019) at SSERC during which he will explore the following questions:

- Is ‘creativity’ associated only with the so-called ‘creative arts’?
- How does ‘creativity’ relate to ‘innovation’, ‘invention’ and ‘entrepreneurship’?
- Is creativity a natural gift, with which the fortunate few are blessed? Or can creativity be taught?

- If it can be taught, what is the process?
- And once an idea is on the table, how can we judge, wisely, whether it is - or is not - a ‘good’ one?

Why not join us for what promises to be a stimulating and exciting professional learning opportunity?

Cost - £100 to include course materials and overnight accommodation.

Pi Equals 3, Bracton Centre (secure mental health unit).

Reference

- [1] <https://www.silverbulletmachine.com/>.

Charging a capacitor

With many schools electing to do what we might call “core” experiments for their Higher Assignments, we thought it would be worth revisiting some of these to give advice on equipment and component values. We are aiming to help teachers and technicians here - beware of passing this material unedited to students. You could be giving them too much information. It is not designed to be a “second source”. We have an evolving document on the Higher Physics area of our website that features a number of what we consider to be suitable experiments. This article showcases one example - charging a capacitor.

Charge versus potential difference

The first experiment investigates the relationship between the charge on a capacitor and the potential difference across it. Measuring charge on a capacitor can be difficult to do. There are charge-measuring instruments called coulombmeters but they can only measure very small charges. We do have a protocol for such an experiment. Please get in touch if you are interested.

In this version of the experiment, we use a variable resistor to keep the charging current constant. We make a note of this current, and find charge Q after a time t using the relationship:

$$Q = It$$

Equipment required:

- 1000 μF capacitor
- 100 $\text{k}\Omega$ linear (not logarithmic) variable resistor
- Smooth dc power supply set to around 5 V, or 3 x 1.5 V batteries wired in series
- Voltmeter
- Ammeter (must be able to read to 0.001 mA or better)
- Stop clock/phone timer

Connect the components as shown in Figure 1 below. If your capacitor is polarity-sensitive (i.e. it matters which leg is connected to the positive side of the circuit as is the case with most electrolytic capacitors), make sure you connect it correctly. It

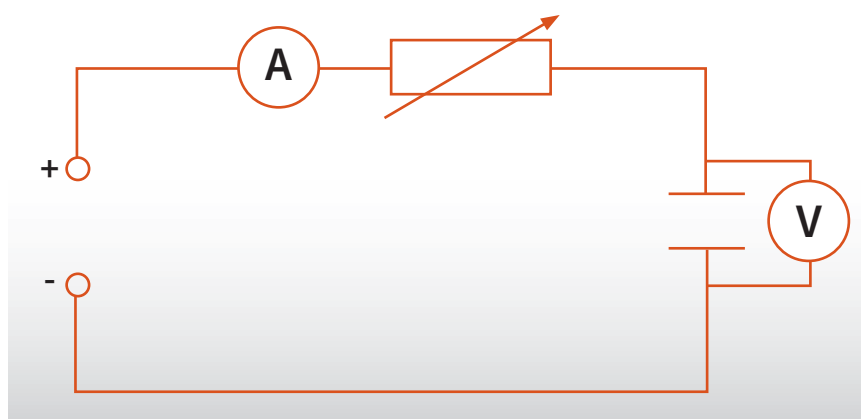


Figure 1 - Capacitor charging circuit.

helps to have more than one person working on this experiment.

Make sure the variable resistor is set to around its mid-point before switching on. What we don't want

is a very low resistance when the capacitor is uncharged. “Short” the capacitor, i.e. connect one side directly to the other. The voltmeter should show a potential difference of 0 V across the capacitor. >>

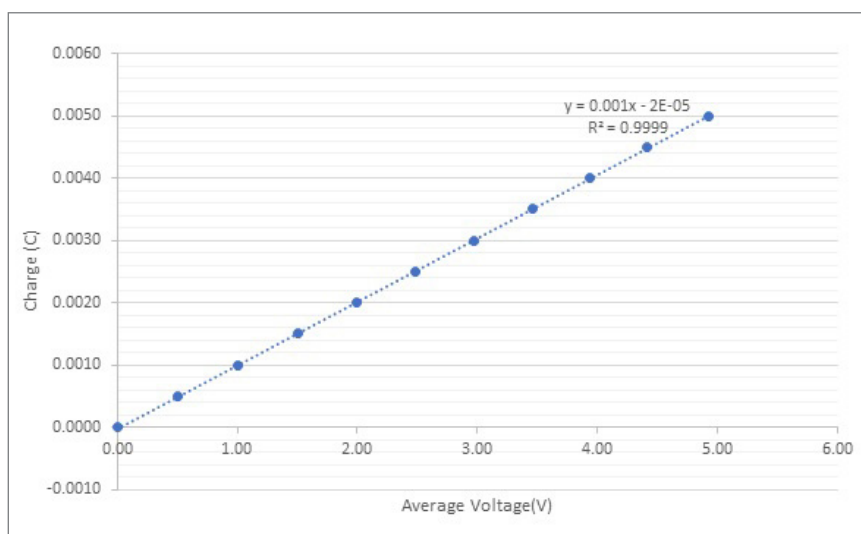


Figure 2 - Charge versus V.

Record the potential difference across the capacitor as 0 V at time 0 seconds.

Adjust the variable resistor until the current on the ammeter is 0.050 mA. This current is suggested because, for the component values shown, the capacitor should take about 100 seconds to charge. 10 readings can be taken, each separated by 10 seconds.

Remove the short and simultaneously start the timer. Throughout this experiment, the variable resistor must be adjusted to keep the current at a fixed value. A small variation will not cause problems.

Record the potential difference across the capacitor every 10 seconds.

You should now have a table of potential difference versus time. In order to study the relationship between potential difference and charge, charge must be found from $Q = It$, where I is the constant current.

Figure 2 shows a sample graph. These results were obtained with a charging current of 0.05 mA. The capacitor had a capacitance of 1000 μF . Although V was the dependent variable, it has been plotted on the

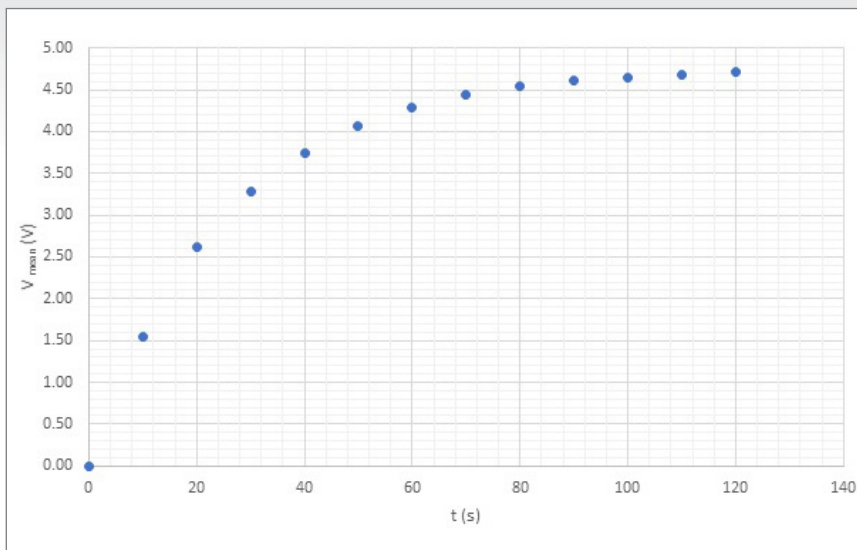


Figure 3 - Potential difference versus time.

horizontal axis because the gradient of the graph should then be the capacitance.

Note that we have chosen fairly large markers on the graph for clarity in this publication. Your students should follow SQA guidance on graph drawing with regard to marker size and type and also gridline spacing.

Potential difference versus time

The graph in Figure 3 was obtained by setting the circuit current, with the capacitor shorted, to 0.200 mA. With the short removed, V was

recorded every 10 seconds. In this experiment, the current was left to its own devices - no attempt was made to keep it constant. An alternative investigation would be to look at circuit current versus time.

Advanced Higher extensions

Though beyond Higher, it is interesting to study the graph of $\ln(V_0 - V)$ versus time, where V_0 is the supply voltage. Such a graph is shown in Figure 4.

The gradient of the graph should be $1/RC$ where R is the resistance and C is the value of the capacitor. RC is also known as the circuit time constant. The potential difference across the capacitor should reach $2/3$ of the supply voltage after RC seconds, and be fully charged by $5RC$. <<

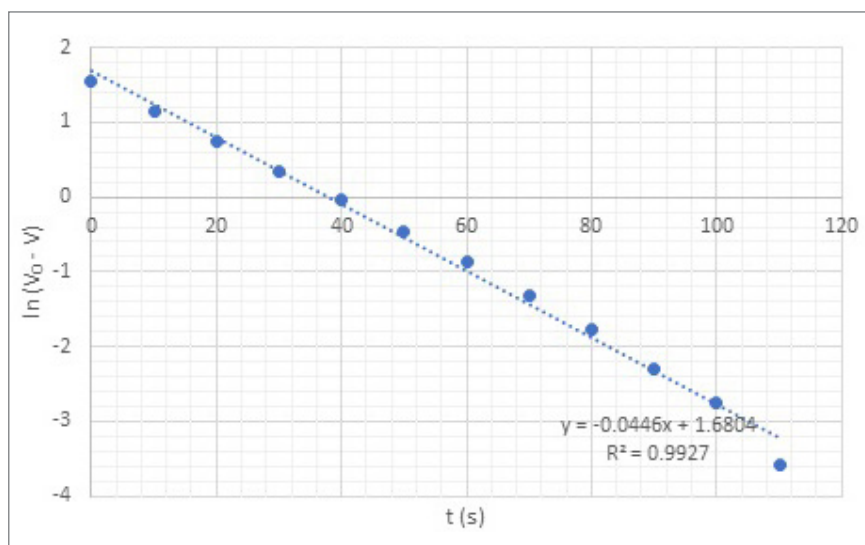


Figure 4 - Logarithmic graph.

Agriculture, food and food security: why it is an important topic for students

We were very fortunate in having Professor Tim Benton as the Keynote Speaker at the SSERC Annual Conference in November 2018.

Tim is Dean of Strategic Research Initiatives at the University of Leeds and Distinguished Visiting Fellow at Chatham House. From 2011-2016, Tim was the UK Champion for Global Food Security, acting as ambassador and spokesperson for matters to do with food and food security, and coordinating work across this area between research councils and government departments.

Quite apart from the intrinsic interest to a wide population, the topic of food security is covered in various SQA specifications [1] including National 5 Biology, Higher Biology, National 5 Environmental Science, Higher Environmental Science, and National 5 Geography.

We were fortunate that Tim gave us permission to record his presentation and we were delighted when he also agreed that we could make it more widely available through the SSERC YouTube channel [2]. We hope that you and your students enjoy the video despite some of the predictions being 'scary'! <<



Professor Tim Benton.

References

- [1] SQA (2019), National Qualifications subjects. Available at <https://www.sqa.org.uk/sqa/45625.html> (accessed 8th February 2019).
- [2] The video is available at https://youtu.be/p-_7KCELPqo.

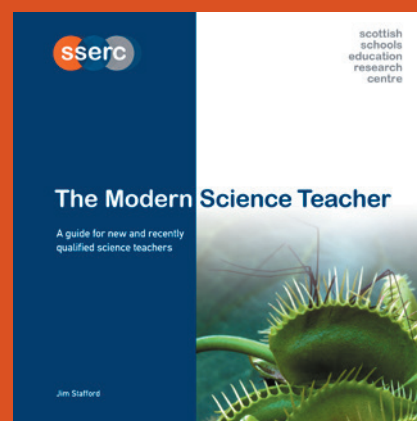
The Modern Science Teacher (reprinted December 2018)

This booklet, written by Jim Stafford, aims to support new and recently qualified science teachers as they embark on their professional careers. The booklet seeks to provide a ready reference point on the key issues that have to be taken into account when devising science courses for the 21st century. Topics covered include the organisation of the science teaching laboratory, CLPL, action research, self-evaluation and school inspections. Although the booklet is intended for those who have just entered the profession it should also be useful to those who support, supervise and manage new and recently qualified science teachers.

In his foreword to The Modern Science Teacher, Professor Graham Donaldson CB makes the following observation:

This booklet is relevant for all science teachers, irrespective of whether they have recently qualified or have been teaching for many years. It supports the reflective and enquiring culture which should increasingly characterise all Scotland's schools and learning communities.

The booklet was updated in December 2018 to include information on SQA qualifications



and HMI inspection procedures. The reprinted version also takes into account a number of other changes since the first edition was published in 2013. A pdf version can be accessed [here](#). <<

The Scottish Universities Science School (SUSS)

Many of you reading this brief article may have started your association with SSERC through attendance at a SUSS event. Without doubt, SUSS is, for the SSERC team, the most complex and challenging event in our calendar. We thought it might be interesting to look back at what has been achieved over the years.



Figure 1 - Lunch at SUSS 2019.

Following discussions with colleagues in the Teacher Education Institutes (TEIs), it was agreed to extend SSERC's involvement with Professional Graduate Diploma in Education (PGDE) students to include subject coverage across the sciences and offer support for practical work in areas outside a student's specialism; thus in 2005 the Scottish Universities Science School (SUSS) was developed. Here, we explore how SUSS has become established as an important feature in the educational calendar.

SUSS programme

SUSS is a two-day, residential event bringing together Biology, Chemistry and Physics PGDE students and graduating science/education students from across Scotland and aims to provide participants with:

- experience in a range of activities not usually available during initial teacher education programmes;
- opportunities to develop expertise in teaching topics outside of their subject specialisms;
- networking opportunities with other teachers of science from across Scotland;

- an introduction to high quality professional development and information on where and how to access further development opportunities;
- information on sources of practical support.

SUSS is timetabled into the PGDE year and takes place in January. For most student teachers this falls between first and second blocks of teaching experience. Attendance at SUSS is voluntary but typically >95% of the eligible cohort attend from across all 10 Scottish TEIs.

The programme includes both subject-specialist and cross-curricular sessions and consists of a mix of hands-on practical sessions, lectures, demonstrations and discussion sessions. Students work through activities much as their pupils might with workshop tutors providing guidance on pedagogy and classroom management.

On Day 1, students are split into groups with colleagues from across the universities depending on their subject specialism (Biology,

Chemistry or Physics). Regardless of their specialism, each student attends a biology, chemistry and physics session. On Day 2, students work in mixed subject groups with colleagues from across the universities. Each mixed group attends the same sessions throughout the course of the day including practical hands-on activities, discussion activities and input from the Teacher Support Organisations.

For most delegates, attendance at SUSS is their first experience of external professional development and we hope that this will be the start of a career-long association with SSERC and the other professional bodies and associations. Such an approach accords well with previous observations [1] that:

'Beginning teachers are at the start of their professional journey, no matter how well prepared they might be by their experiences during initial teacher education.'



Evaluation

Student feedback

We report here on cumulative evaluations of SUSS for the period 2013-2018. From 2013-2018 there were 1048 attendees at SUSS representing >95% of the eligible cohort. Students are asked to complete evaluations prior to their departure from SUSS; typically, the response rate is 80+%.

Students are asked to rate their overall experience of SUSS from 'very good', 'good', 'average' or 'poor'. Results are overwhelmingly positive with 99.1% reporting their experience to be either 'good' (12.4%) or very good' (86.7%). Across the years only 7 individuals have reported that their experience was 'average' (0.8%) and 1 individual reported their experience as 'poor' (0.1%). The majority of these 'less positive' comments refer to aspects related to the accommodation.

Students are asked to rate the individual sessions in providing them with information to use in their teaching and professional development from 'very useful', 'useful', 'of some use', 'of little/no use' or 'N/A' if a student had not attended the session. The most popular sessions were the subject focussed sessions with a minimum of 94% of students finding these to be 'useful' or 'very useful'. For all subject specific sessions, students particularly enjoyed the practical activities and the ideas they gained from them:

- *The experiments were great, perfect for the classroom, great resources.*
- *Great ideas for teaching science and making science exciting in class!*
- *Lots of good activities that are cheap and accessible.*
- *Very interesting to do the practical and see what challenges pupils might face.*



Figure 2 - A subject workshop.

Students report that sessions have improved their subject knowledge, helped to address misconceptions and improved their confidence, particularly in teaching topics that are outside their subject specialisms:

- *Learnt a lot! Didn't realise how little I knew about photosynthesis.*
- *This session was useful and cleared up a few of my own misconceptions.*
- *Fantastic, very useful and helped build my confidence in an area I'm weakest.*

Students also felt that sessions were well delivered and that the enthusiasm and knowledge of all the presenters resulted in lots of tips and guidance for improving learning and teaching in the classroom:

- *Good practical and reflective advice of classroom teaching.*
- *Informative, well presented, excellent resources and ideas.*
- *Really interesting to hear from a teacher's point of view.*

What students enjoyed most about the evening lectures and keynote sessions was that they were inspiring, motivational and entertaining. Students felt that invited speakers were good role models and found their perspectives

to be interesting and engaging. Many remarked that the keynote was an enjoyable and appropriate way to start the event and the evening lectures were a good way to end Day 1.

The 'Teacher Support Organisations' and 'What can SSERC do for you?' sessions were particularly useful for building students' professional networks and for providing information about support and further development opportunities:

- *Didn't realise there was so much support for teachers.*
- *Great to put names to faces for organisations and to build professional network*

Tutor feedback

Several TEI tutors were interviewed at SUSS 2018 and their feedback was also very positive. SUSS is held in very high regard by tutors and is seen as a great opportunity to expose their students to high quality professional development at an early stage in their careers and this is confirmed by Findlay [2] who, in her article about science teacher education in Scotland, highlighted that SUSS is 'An important and enjoyable part of PGDE science courses across Scotland'.





Figure 3 - Song and dance routines from members of the SSERC team 'help the experiments go down...?'

In SSERC we believe that our close partnership with TEI tutors is responsible for SUSS routinely attracting such a large proportion of the available student cohort. Tutors feel that SUSS represents an invaluable opportunity for their students to network with others from around Scotland and to begin to build their professional networks.

Success factors

We believe the following have been key to the success of the SUSS model:

- Our partnership with TEIs is robust ensuring that we attract the vast majority of the available cohort each year.
- There is a real opportunity for delegates to network with virtually all their fellow student cohort from across Scotland.
- All presenters are experienced practitioners with relevant practical advice and guidance.
- We focus on experiential activities which are not normally part of the initial teacher education experience.
- The programme is designed to allow participants to develop expertise outside of their subject specialism in areas which they will be required to teach.
- The timing of SUSS in the academic year means that students can try out the ideas/activities covered at SUSS during subsequent teaching experience placements.

- Our chosen venue (an out-of-city, quality hotel) changes the tutor-student dynamic and ensures that everyone is treated equally as professionals. It also provides an immersive residential experience.
- Student teachers gain a deeper understanding of the level and variety of professional support which is available to them and are given information on how to access further support and development opportunities throughout their future careers.

The future?

There is no reason, in principle, why the model of SUSS could not be extended to other parts of the UK. In England, because of the absolute number of student teachers, it would probably make sense to bring groups of PGCE providers together on a regional basis.

In our view the model and structure of SUSS could also be extended beyond the secondary sciences.

Other secondary curriculum areas might benefit from an early 'large-scale' intervention at a national level. In this regard we can report that the Scottish Government has provided SSERC with funding to run a pilot event (the Scottish Universities Technology School [SUTS]) for PGDE students who are following either Design & Technology or Technological Education routes into teaching and our first such event was held in December 2018. Feedback from SUTS 2018 was very positive and we plan to run more such activities going forwards.

We feel that the primary education sector could also benefit from the SUSS model. We recognise that those following routes into primary teaching often lack confidence, and in some cases competence, in the teaching of experimental science. Events like SUSS with a focus on the primary curriculum would offer rich opportunities to address some of these issues. A particular challenge in this regard would be the number of PGDE Primary entrants (the target for 2018/19 entry in Scotland was 1200 [Scottish Funding Council, 2018] although with sufficient resource in place we believe that the quality of learning and teaching in the classrooms of probationer teachers would be much enhanced at a time when the Government's STEM Strategy [3] calls for such change.

A fuller version of this article appeared in *Science Teacher Education* - see [4].



References

- [1] Patrick, F., Elliot, D., Hulme, M. and McPhee, A. (2010), 'The importance of collegiality and reciprocal learning in the professional development of beginning teachers', *J. Education for Teaching: International Research and Pedagogy*, **36**, (3), 277-289.
- [2] Findlay, M. (2017), 'Science teacher education in Scotland', *Science Teacher Education*, **80**, 33-45.
- [3] Scottish Government (2017), 'Science, Technology, Engineering and Mathematics - Education and Training Strategy for Scotland'. Available at <http://www.gov.scot/Resource/0052/00526536.pdf> (accessed 28th January 2019).
- [4] Andrews, K., Beaumont, P., Bissett, E. and Crawford, K. (2018), The Scottish Universities Science School, *Science Teacher Education*, **83**, 7-15.

SSERC professional learning courses



Our professional development courses range from twilight events, day-courses through to residential meetings lasting up to 6 days in total. Our curriculum coverage spans both primary and secondary sectors and we offer events for teachers as part of their career long professional learning, newly qualified teachers and technicians. Many of our events receive funding from the ENTHUSE awards scheme or the Scottish Government.

Courses available for online booking include:

COURSE NAME	RESIDENTIAL?	DATES	CLOSING DATE	SECTOR
Computing Science: Enriching Opportunities across the BGE Curriculum 3rd & 4th Level	No	10 April 2019	10 March 2019	Secondary
Discovering Micro: Bits across the BGE	No	30 April 2019	30 March 2019	Secondary
Safety in Microbiology for Schools	Yes	1-3 May 2019	15 March 2019	Secondary
Welding Skills	Yes	9-10 May 2019	4 April 2019	Secondary (Technology)
Safe Use of Smaller Fixed Workshop Machinery	No	13-14 May 2019	29 March 2019	Secondary (Technology)
Reaching all Learners using Digital Tools	No	14 May 2019	14 April 2019	Secondary
Chemistry Summer School	Yes	16-17 May 2019	05 April 2019	Secondary
Introductory Physics	No	22-23 May 2019	29 March 2019	Secondary (Technician)
Welding Skills	Yes	23-24 May 2019	19 April 2019	Secondary (Technology)
Creativity	Yes	27-28 May 2019	18 April 2019	All
Supporting Learning using Rich Media	No	28 May 2019	30 April 2019	Secondary
Physics Teachers Summer School	Yes	29 May-1 June 2019	01 April 2019	Secondary
RSoB Annual Teachers Meeting	No	30 May 2019	30 April 2019	Secondary
Safe Use of Fixed Workshop Machinery	No	5-6 June 2019	30 April 2019	Secondary (Technology)
Fabrication skills	Yes	10-11 June 2019	10 May 2019	Secondary (Technology)
Chemical Handling	No	12-13 June 2019	3 May 2019	Secondary (Technician)
Safe Use of Fixed Workshop Machinery (Refresher)	No	14 June 2019	30 April 2019	Secondary (Technology)
Science for Curriculum Leaders and Heads of Faculty	Yes	19-20 June 2019 & 17-18 December 2019	17 May 2019	Secondary
Biology Summer School	Yes	25-27 June 2019	30 May 2019	Secondary
Primary Summer School	Yes	4-5 July 2019	31 May 2019	Primary

Please check our website pages at <https://www.sserc.org.uk/professional-learning/calendar/> for the most up-to-date details on our career long professional learning calendar.

Voltage values for **safe circuits**

We are now issuing the following advice on voltage levels for circuit building in schools:

- Pupils and students should carry out such work at no more than 30 V, irrespective of whether ac or dc is used.
- If there is a chance of touching an uninsulated conductor with wet skin, or of touching an uninsulated wet conductor, the limit becomes 15 V.

This is slightly different to what we said in an in-depth article about electrical safety in 2003 [1], though much of the information in that piece is still useful. We have based our advice around the concept of a “hazardous live”. According to the British Standard we use for guidance [2], if something is hazardous live it is capable of causing an electric shock or burn. The version of the standard in use in 2003 stated that smooth dc above 70 V could be considered hazardous live, as could ac or unsmoothed dc above 33 V. This was for dry conditions. The limits for wet conditions were half those for dry.

The latest version of the British Standard has set the dry limits lower, at 60 V and 30 V respectively. Having discussed the issue with our friends at CLEAPSS and ASE, we have decided on the 30 V ac and dc limit for the following reasons:

- There is no educational justification for carrying out circuit work at voltages between 30 V and 60 V dc.
- It is not always obvious whether a dc supply is smooth without testing it. Not every teacher or technician will be confident in applying the test, which would involve examining the output using an oscilloscope.

The advice also applies to the use of apparatus such as ray boxes, motors and heaters that students might connect to a power supply. There may be circumstances where a smooth dc voltage greater than 30 V (but not

60 V) for open circuit work can be justified. A specific example, gel electrophoresis, is described below. Please contact us to discuss any other activities you have in mind.

Gel electrophoresis

The National Centre for Biotechnology Education (NCBE) has developed activities on gel electrophoresis that feature on the SSERC website [3] and in some of our workshops. For the electrophoresis process to run in a reasonable time, it was common to connect 3 x 9 V batteries in series. NCBE then produced a 36 V dc power supply. We feel that we can justify student use of these voltages provided that:

- There is close supervision;
- All power supplies are switched off and unplugged from the mains while tanks are assembled and connections made.

For electrophoresis experiments using greater voltages, shrouded leads **must** be used and the equipment **must** have interlocks. An example of an interlocking system would be an electrophoresis tank where the power supply remains electrically disconnected unless a protective lid is locked in place.

You can read more about control measures when working with hazardous live voltages in Bulletin 253 [4] but note that the older voltage limits (e.g. 70 V instead of 60 V) are quoted in this article.

Smooth and unsmooth

Figure 1 shows how the outputs of different power supplies vary with time. Any dc that is not ripple-free is said to be unsmooth. The ripple may not necessarily be as pronounced as that shown in the middle image. >>

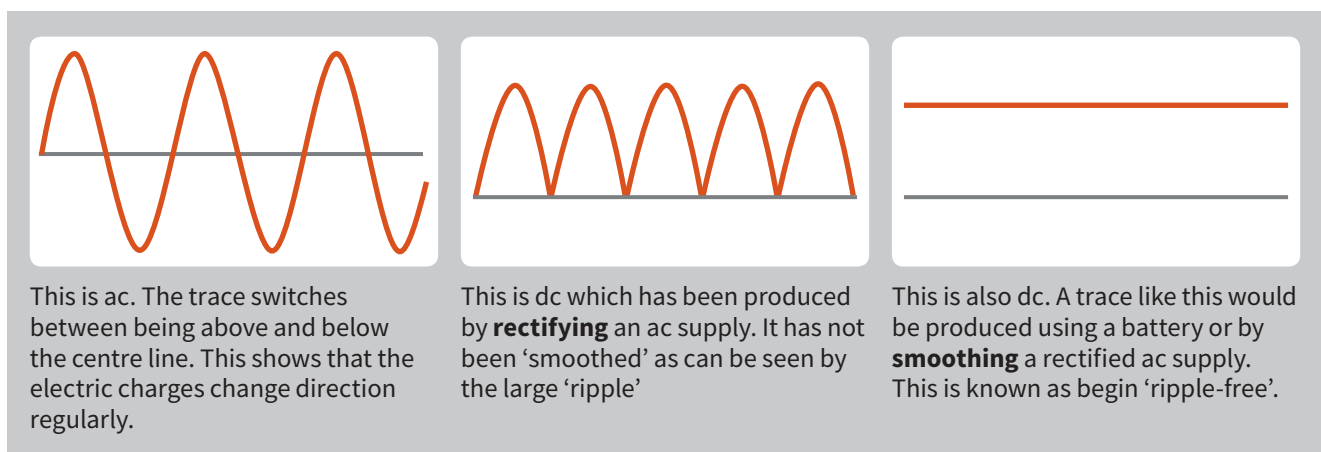


Figure 1 - Ac, unsmooth dc and smooth dc.

ac versus dc

Why are the limits for ac lower than for smooth dc? The effects of electricity on the body are complex, but we do know that the higher the current in the body, the greater the chance of harm. It is also true that if voltage increases, current increases. All materials have an electrical property called impedance. The lower the impedance, the higher the current for a given voltage. If you have studied physics to Higher level but not beyond, you might be thinking, "This impedance sounds just like what we called resistance." You would be partially correct, and a human body does indeed have a resistance. However, it also has a property called capacitance that contributes to a reduction in the body's overall impedance. This contribution depends on the frequency of the electrical source, i.e. how many times the output changes per second. Smooth dc is unchanging with time unlike ac

and unsmooth dc. The bottom line is that the body's impedance is less for unsmooth dc or ac than for smooth dc. For the same voltage, ac or unsmooth dc will cause a larger current in the body than smooth dc. This is one reason why the smooth dc voltage limit is higher. <<

References

- [1] SSERC Bulletin 208, Working with HT supplies, electrical safety.
- [2] BS EN 61010 Safety requirements for electrical equipment for measurement, control, and laboratory use.
- [3] <https://www.sserc.org.uk/subject-areas/biology/higher-biology/dna-and-gene-expression/> (accessed January 2019).
- [4] https://www.sserc.org.uk/wp-content/uploads/2018/10/SSERC_bulletin_253_p13-15.pdf (accessed January 2019).

Locust allergy

Allergy to locusts has been reported as an occupational allergy found in research staff working with repeated exposure to large breeding colonies of locusts. A proportion of these workers (invariably less than 50%) may become sensitised to locust allergens and of these a proportion may exhibit symptoms of asthma, rhinitis, dermatitis or conjunctivitis. There is some evidence that workers with previous allergies may be more susceptible. Such allergies develop slowly with prolonged contact with locusts. The major source of locust allergen is found in locust faeces arising from the epidermal cells of the mid-gut and ceca [1].

The key to reduce the risk of sensitisation to locust allergens is avoidance. For short-term studies (until the adults reach the end of their natural lives after a few weeks), the risk of allergic reactions is low. Locusts should not be maintained in continuous culture; it is safer to buy in locusts when needed rather than attempt to maintain a permanent culture [2]. Nevertheless, care must be exercised when cleaning out the cages to avoid raising dust. Cages should be constructed of material that is easily cleaned, is non-absorbent and is not perforated [3]. Simple plastic aquaria or vivaria can be suitably adapted to house small numbers of locusts. The sand tubes in commercial cages should not be used and the holes in the flooring should be blocked off. For the small stocks

of locusts likely to be encountered in schools gloves and a dust-mask covering mouth and nose should provide sufficient personal protection where it is required.

The following information should be useful in forming the control measures of a risk assessment:

- Determine if the pupil (or indeed teacher or technician who may be involved in handling locusts) has a history of allergic conditions and if so their relative severity.
- Do not attempt to set up a breeding colony of locusts. Rather buy in locusts as required. Maintain the locusts in a suitable container. Homemade wooden and muslin containers are not suitable.
- Avoid raising dust when removing locusts from the container for experimental purposes. You may wish to consider transferring locusts to a 'holding container' prior to experimental use. Handling locusts involves a low level of risk of allergic reaction or sensitisation. Wash hands immediately after handling locusts.
- When cleaning containers in which locusts have been maintained avoid raising dust, wear gloves and a dust-mask covering mouth and nose and work in a well-ventilated area.
- Consider if removing locusts to a 'holding container' for use and the cleaning of containers in which locusts have been maintained should be carried out by the pupil or by a technician/teacher. <<

References

- [1] Meir Paul Pener, (2014), Allergy to Locusts and Acridid Grasshoppers: A review, Journal of Orthoptera Research 23(1):59-67, <http://www.bioone.org/doi/full/10.1665/034.023.0105>.
- [2] Keeping and Housing Animals, L56, CLEAPSS. 2017, <http://science.cleapss.org.uk/Resource/L056-Housing-for-animals.pdf>.
- [3] Animal Allergy including that to Laboratory Animals - Policy and Guidance, University of Cambridge Health and Safety Division, 2004, <https://www.gurdon.cam.ac.uk/staffonly/forms/safety/biologicalsafety/UsefulInfo/Allergy>.

Involving students in safety

'Advanced Higher students carrying out project work can write their own risk assessments. True or False?'

This is a question we often ask at SSERC health and safety courses and most people answer, "True, but the risk assessments should be checked by a teacher." It's a good answer and one that often leads to discussion on how we can involve young people in risk assessment from an early age. Many teachers, perhaps subconsciously, do this from day 1. A secondary science teacher may, when running the first practical with a new S1 class, ask them what they think the hazards are in the activity and how the risk could be managed, though they might not use this language.

- What could harm you in this experiment?
- How are you going to keep safe?

Risk and risk management is specifically mentioned in CfE at all levels in Broad General Education:

'I am learning to assess and manage risk, to protect myself and others, and to reduce the potential for harm when possible.'

**HWB 0-16a/HWB 1-16a/HWB 2-16a/HWB 3-16a/
HWB 4-16a**

In addition, some courses such as Skills for Work: Laboratory Science at National 5 and Advanced Higher Chemistry require students to produce formal risk assessments as a part of the course. The following strategies, along with the aforementioned questioning, should help students develop skills in risk assessment and risk management. It helps if we make it clear to students that risk assessing is a process. The outcome of the process is a document, a risk assessment, which is a record of the process and which contains the control measures needed to carry out the activity safely.

Help students distinguish between hazards and risks

A hazard is something that can cause harm, like electricity. Risk combines the likelihood of something going wrong with the severity of harm should it do so. Use examples such as crossing the road. Whether you cross the school playground or the M8 motorway on a Saturday afternoon, the hazard is the same - being struck by traffic. However, there is usually very little traffic in the playground, so the chances of being hit are small, and vehicles generally move slowly, so any injury is unlikely

to be severe. Contrast this with the M8, where there is much more traffic and consequently a greater chance of being struck. The traffic tends to move so fast that any impact is going to result in a life-changing injury if not death. Starting with the same hazard, we have two vastly different risks, one which is easily reduced further by looking both ways, the other being intolerable no matter what control measures you put in place.

When we say that a risk is intolerable, we mean that there is no way to carry out the activity safely. Some risks are trivial - no control measures are required. In the middle ground are risks that are tolerable provided certain control measures are implemented.

"Move along, nothing to see here"

Emphasise that some activities have no significant hazards and that if this is the case, nothing more needs to be done. Nothing undermines Health and Safety more than the elevation of trivial hazards into significant risks, requiring all sorts of pointless control measures. Eye protection does not need to be worn when a trolley is rolled down a slope. There is a real danger of being seen to 'cry wolf'. If you insist on eye protection for all activities involving 'chemicals' then there is the danger that students will become blasé due to having to wear them for substances they know are harmless, vinegar or salt solution for example, and this could lead to them assuming that the eye protection simply isn't that important.

Model the behaviour you expect

Insisting that students wear eye protection then not wearing it yourself may suggest to students that eye protection is just a nag dreamed up by you to exercise your authority. Or perhaps they will feel they have been made to dress up as scientists.

Don't get students to dress up as scientists

If students require a lab coat or safety glasses in order to protect themselves, fine. If not, they should not wear them. Personal protective equipment is not a uniform that identifies someone as a scientist. Indeed, the Royal Society of Chemistry has resources based around the theme, 'Not all chemists wear white coats'. Work where lab coats must be worn represents only a subset of science. We have heard some primary teachers say that their children love wearing white coats (or a parent's old white shirt) for science, but we have to ask whether the same teachers would have their pupils wear artists' smocks when drawing with pencils. This is an area where we would genuinely like to hear your views. >>>

Teach older students to be systematic

There may be general hazards in an activity-slips, impact, cutting etc. It may help students to comprehensively cover other hazards by grouping them. For example:

- Fire
- Chemical - toxic, corrosive, flammable, irritant
- Electrical
- Radiation - ionising and non-ionising
- Biological - materials of living origin, microbiological

Talk about risk assessment and the workplace

Students should be aware that they must follow safety advice and if they don't, they cannot take part in practical

work. It is worth explaining to all students that in the workplace, risk assessments are carried out. Safety advice is then drawn up and communicated to staff. The consequences of failing to follow your employer's safety guidance could be disciplinary measures up to and including dismissal.

In school, in the workplace and in life in general it is impossible to eliminate risk. CfE recognises the importance of young people assessing and managing risk. In school science and technology departments, we have an unrivalled opportunity to develop their skills in this area. <<

Keeping in touch

Website access

Apologies to those of you who have fallen foul of a glitch in our system. You are supposed to be able to set/reset your own password but when attempting to do so while not logged in (having forgotten your password for instance) the link you have been sent to click on to confirm has been telling you it is invalid.

We think this has now been fixed. If you are still having problems accessing the website then do get in touch and we will sort it out.

Maintaining access

We have had the occasional request for the ability to make a printed version, particularly of the Hazardous Chemicals advice. The previous website allowed you to simply print the pages (a bit clumsy but it worked) but the new tabbed layout, while giving a much better browsing experience, makes this nigh on impossible.

So we have now produced a printable version of the Hazardous Chemical information from the pages. Note this does not contain the concentration calculator or the experiment guides but it will give you the necessary health and safety information.

This raises other issues. Such as why would you want to? To be fair, there are plenty of people who are happier seeking out the information on paper. That is perfectly reasonable.

We have come across a few cases where technicians are being told they have to have a paper copy - we assume as some sort of a backup. There are a few scenarios that could be put forward to justify this:

Scenario 1: the school does not have WiFi or wired internet access (or more likely it is not accessible in the Technician Base). Frankly, these days internet access for technicians is not a luxury: it is an essential. Technicians need access for a variety of aspects of their job so the school simply needs to sort this out.

Scenario 2: the internet has gone down. Possible but it is not very common and it is rare that the outage will last a long time. Given that our website is accessible by mobile device, the small amount of checking of safety information that may be needed during the outage can be done easily by phone or tablet.

Scenario 3: There is an incident in the prep room or elsewhere in the school. In fact this is an argument **against** using a paper version. Unless you remember to pick up the bulky file when evacuating or you have another copy elsewhere in the building then you will not have access. The internet will allow you to access our website at any time.

One more point is that as the website is being constantly updated, your paper copy may be out of date. It will be updated from time to time but realistically this will not happen more than annually at most.

So, if you want to print the Hazardous Chemicals advice, feel free, though you will be sacrificing several trees to do so (the document comes in at 550 pages!) but don't feel that you have to. <<

The heat is on

One of the core activities in chemistry at all levels is heating substances. This is usually done with little fuss and few accidents. The presence of naked flames and hot objects or substances is, however, a significant hazard so a review of methods and techniques for heating chemicals seems timely.

Burners

The most common method of heating in the school chemistry laboratory remains the use of the Bunsen burner or using some other type of burner.

Bunsen burners

The means used overwhelmingly more than any other in a chemistry laboratory is the Bunsen burner. Despite having been in use since 1857, it has not really been bettered. The presence of a hot, naked flame though does raise a few issues that need to be addressed for its safe use:

- 1) Ensure you purchase the correct type of burner for your gas supply. The two types of gas require different size jets and ratios of oxygen to burn efficiently and it can be dangerous to use the wrong type.
- 2) Use appropriate tubing.
 - a) The traditional orange rubber tubing is fine but it perishes on exposure to hydrocarbons and should be closely inspected at least annually and damaged tubing replaced.
 - b) Thick-walled nitrile tubing (usually black) will not perish but is quite rigid and in use the tension in the tubing can result in the Bunsen burner being overturned.
 - c) The best option is thinner walled, more flexible, nitrile tubing which is usually grey.
 - d) There is no need to have the reinforced end pieces. If they are fitted, be careful not to remove the pipe from the gas taps by pulling on the tubing as this can cause the end piece to work loose.
- 3) A naked flame is not suitable for heating flammable substances, such as ethanol or propanone. If these need heating, other methods should be used such as a water bath.

Other gas burners

It used to be possible to get attachments to fix to camping gas cylinders that would allow them to be used as Bunsens.

These have never been a good idea but recent changes to regulations mean that they should not be used in the laboratory. They should not be available from any



Figure 1 - Attachment for camping gas cylinder. NOT to be used in schools (image Lilly_M under Creative Commons license 3.0).

reputable school supplier but are still to be found on Amazon and Ebay and from overseas. If you have any, they should be disposed of.

It is possible to purchase properly designed portable butane burners (see Figure 2) these have a heavy base making them perfectly stable and are a good alternative if you are working in a room without a gas supply or perhaps out doing fieldwork.

Spirit burners

These are simple glass jars with a wick that typically burn ethanol (usually in the form of methylated spirits).

They can be purchased from most suppliers or you can make your own from mini jam jars (see Figure 3).

The safety issue here is that there is a reservoir of highly flammable liquid that could spill in the event of being knocked over. With moderate care, though, this is not likely as both designs are quite stable.

The size of the flame is determined by the wick rather than the amount of fuel in the burner's body so it is best if this is kept as low as required for the session.

If the burners are being stored for any length of time, they should be emptied of fuel. When being stored in the short term, a lid is a good idea to reduce evaporation of the ethanol; for safety as well as for reducing the need for refilling. >>



Figure 2 - A butane burner.

Electrical heaters

These are very useful in situations where the presence of a naked flame is dangerous - especially when working with organic solvents which are often highly flammable.

As electrical devices, it is important that these are PAT tested at appropriate intervals and that before use they are given a quick visual inspection to ensure they seem safe.

Hot plates - These heaters consist of a flat hotplate that flasks and beakers can be placed on. They are often combined with a magnetic stirrer - a very useful facility. In theory, they claim to heat up to 300°C or more. In practice it is difficult to get this high due to heat loss from the beaker/flask to the surroundings.

Heating mantles - these are more specialised heaters, designed for use with round-bottomed flasks particularly during organic chemistry. Again, there can be issues with heat loss to the environment preventing high temperatures being achieved.

TIP

If you wrap aluminium foil around your flask on either a hotplate or a heating mantle, it will reflect back much of the heat and allow you to achieve a higher temperature.

Electric 'burners'

Unlike other electric devices, these 'burners' produce a high intensity stream of heat and can be used to replace a Bunsen burner - apparently achieving temperatures of 900°C.



Figure 3 - Homemade spirit burners.

With these sorts of temperatures, great care should be taken to avoid things such as overheating of substances (e.g. oils), ignition of flammable solvents etc.

Ovens - a laboratory oven can be set to heat a substance for a set period of time at a set temperature. They are designed to maintain the temperature more accurately than domestic ovens but are less widely used than might be the case as it is not possible to observe any changes taking place within the oven. They are, however, invaluable for drying solids for accurate making up of solutions or for other preparations. Incubators work in a very similar way but at lower temperatures, mainly for incubation of microorganisms.

Hairdryers - while not used much for actual heating, they are often used for drying things such as chromatograms. They can also be used for some heating experiments such as that of the cobalt chloride mixture in the demonstration 'equilibrium and Le Chatelier'. Care should be taken when purchasing cheap hairdryers to ensure they are of a suitable standard: for instance, those that have a switch between 110 and 220 V and not suitable for use in schools.

Microwaves - while not widely used in schools, microwave ovens are growing in use in laboratories. They are not suitable for all purposes but can be used to heat certain substances much more rapidly than might be the case otherwise. There are a few specific issues to be wary of:

- 1) Metal items, including spatula, aluminium foil etc., should not be placed in a microwave under any circumstances. They can rapidly heat and ignite causing serious damage.
- 2) Non-polar substances are not affected by microwaves so cannot be heated this way.



Health & Safety



Figure 4 - A heating mantle wrapped in foil to help achieve higher temperatures.

- 3) Some solvents such as water can easily become superheated on a microwave, meaning that when disturbed they can instantly boil and may deposit boiling water over your hand.
- 4) Flammable substances produce vapour when heated and this is trapped in the microwave chamber. Ethanol, for instance has a flashpoint of only 13°C and so the slightest spark can easily ignite the vapour potentially causing an explosion. Unless you are certain of your solvent, stick to just using the microwave for aqueous mixtures.

'Baths'

Heat can conveniently be applied to substances by immersing their container in a fluid of an appropriate temperature. In all cases, care must be taken to ensure that hot liquids are not spilled as they can cause nasty scalds and burns - especially oil.

Water baths are the most commonly encountered. For longer heating or large quantities, commercial water baths should be purchased: These are filled with water and the water is heated and maintained at a specific temperature by a thermostatic control. They are particularly useful for biological experiments.

On a small scale, you can simply heat a beaker (or other container of water) remove the flame and then place a test tube of your substance in the water - for removing chlorophyll from a leaf for instance.

Oil baths work in exactly the same way but as oils can be safely heated to over 200°C higher temperatures can be achieved. Care should be taken to avoid overheating and hence a fire.

Sand baths are most commonly used in conjunction with a hotplate. If the hot sand is piled up around the beaker/test tube, it ensures the heat comes from the sides as well as the base and this can speed up the reaction as there is less reliance on convection to distribute the heat.

Conclusion

The main risk from all of these techniques comes from the heated substance itself: either simply by exposure to hot liquid/solid and getting a burn/scald or perhaps from properties of the chemical itself due to flammability of solvents such as ethanol or potential explosivity of things like ammonium nitrate. In addition, when heated some substance will emit dangerous fumes; in these cases, the heating should be carried out in a fume cupboard.

So as well as ensuring you know the dangers associated with the technique you have chosen, it is also vital that you are aware of any hazards from the chemicals you are using. If you are unsure, contact us here at SSERC for advice. <<



Figure 5 - An electric 'burner'.