HSE Guidance on the safe use of Vacuum Lifting Equipment (Vacuum Lifting Tubes and Attachments)

Introduction

1. This document describes the use of vacuum lifting equipment and provides advice on safeguards to be employed against possible hazards when planning and carrying out work activities involving the use of vacuum lifting equipment. This information was previously included in HSE Operational Circular OC 234/9 "Vacuum Lifting Attachments" and OC 234/12 "Vacuum Lifting Tubes" and their associated information documents.

2. This guidance is considered good practice but it is not compulsory and may not be applicable in all circumstances. You may however find it useful in deciding what is required to comply with the law to reduce the risk of injury to operators and other persons and to avoid damage to plant and equipment etc.

Vacuum lifting equipment

3. Vacuum lifting equipment is widely used in many industrial sectors for the lifting and handling of materials/components that have a flat or smooth surface. In particular materials such as metal or glass plates, concrete slabs, pipes, plaster boards, plastic laminates, cement bags, beer kegs and tins etc. can be easily lifted and handled using vacuum lifting equipment. Vacuum lifting equipment utilises suction pads (in place of conventional lifting accessories) for the purpose of attaching and lifting loads.

4. This guidance covers 2 basic types of vacuum lifting equipment:

- Vacuum lifting tubes (VLT) – a lifting system (machine) incorporating a vacuum tube with suction pads used for both gripping and lifting the load.
- Vacuum lifting attachments (VLA) – a detachable lifting attachment incorporating suction pads that is fixed to an independent lifting machine (e.g. attachment to a crane or hydraulic excavator arm or forklift truck). The attachment is used for gripping the load and the machine used to lift the whole assembly.

The difference between a VLT and a VLA is that VLT is used for both gripping and lifting the load, but a VLA functions as an attachment for gripping the load.

Vacuum Lifting Tubes

5. A Vacuum Lifting Tube is a lifting machine that comprises of:

- a vacuum suction pump, producing an average pressure differential of approximately 550 mbar;
- a lifting gantry/frame with means/accessories for attachment of the component parts of the lifting gantry/frame (e.g. a swivel connector);
- a vertically collapsible wire reinforced fabric tube attached with one or more suction pads.

6. Manufacturers/suppliers of this equipment normally supply it on the basis of pre-supply tests carried out on the actual loads and packaging to be lifted. Assessment of the physical layout of the shop floor area into which the equipment is installed is normally included. It is therefore important that

duty holders should not change the use of their VLT equipment to other products without prior consultation with the suppliers of the equipment.

Vacuum lifting tube design and operating principles

7. A vacuum lifting tube utilises the creation of a vacuum via the suction pads to attach itself to the object being lifted. An electric-powered suction pump is used to create the vacuum allowing the suction pads to seal directly onto the object being lifted. The cross sectional area of the lifting tube is fixed at approximately half that of the total cross sectional area of the suction pad(s). It is likely however, that this value could vary slightly between different manufacturers of this equipment.

8. This area ratio ensures that at the instant sufficient vacuum is applied to the lift tube to lift the load; the gripping force via the suction pad attachments is therefore twice that of the load, thus reducing the likelihood of the load becoming detached and falling.

9. The vacuum within the system can be varied using a hand operated control valve, thereby making it possible to raise and lower the load in a controlled manner. The control valve is fitted with a handle which enables the load to be positioned with a minimum amount of effort.

Vacuum lifting tube possible modes of failure

10. The attachment of the lifting tube to the lifting gantry usually comprises a rotary vacuum seal which enables the tube/load to swivel through 360º. This seal is safety critical and should be inspected at intervals determined by a suitable risk assessment procedure.
11. The whole lifting system is dependant upon the vacuum pump for its safe operation. In the event of pump failure, VLT incorporate a one way valve located in the top of the lifting tube that automatically closes thereby maintaining the vacuum in the lifting tube. Should the vacuum reduce to an equivalent force that is less than the force exerted by the load, then the load will be automatically lowered

12. The corrugated lifting tube is subjected to compression at every lifting operation hence its selection is extremely important.

13. The lifting tube is a safety critical component which generally comprises of a wire reinforced rubberised fabric tube. This tube is subjected to a negative pressure (vacuum) and has a number of possible failure modes which should be addressed during the design and selection stage:

- the wire reinforcement will be subject to torsional stress variations during its lifetime as a result of repeated compression of the tube during lifting operations leading to possible fatigue failure;
- the pitch of the reinforcement wire should be adequate to support the tube fabric against vacuum thus minimising the risk of tearing and fabric/reinforcement bond failure;
- excessive extension of the bellows will result in insufficient support of the fabric by the reinforcement resulting in fabric failure;
- failure of the fabric tube due to environmental attack (ageing) should be considered.

14. It is recommended that a thorough inspection and maintenance system be implemented which pays particular attention to all safety critical components.

Vacuum lifting tube possible hazards during use

15. Mechanical damage to the lifting tube fabric resulting in release of the load.

16. The lifting of the loads is achieved by the attachment of the suction pads to one or more faces of the load. The user must ensure that the packaging surrounding (carrying) the load is adequate for the load it is subjected to (not forgetting the underside of the packaging).

Vacuum Lifting Attachments (Vacuum Lifters)

17. A vacuum lifting attachment also utilises the creation of a vacuum via the suction pads for attaching itself to the load being lifted. It can be a single suction pad as well as multiple suction pads. The attachment incorporates a number of suction pads that fit directly onto the surface of the load thus enabling a vacuum to be created between the suction pads and the load. The suction pads are an integral part of the lifting attachment. Where an electric-powered suction pump is used, it can be an independent unit that is connected to the lifting attachment by piping or for non-fixed vacuum lifters integral with the attachment forming a complete detachable lifting accessory. The lifting attachment is generally suspended from lifting equipment (e.g. hoist /crane /excavator) and can be attached by means of a hook arrangement, accessories or other mechanical means. The vacuum attachment can also be an integral part of the lifting equipment.
There are 4 basic types, of Vacuum Lifting Attachments: (reference: EN 13155)

- the self-induced (non-powered) Vacuum Lifting Attachment;
- the power-operated Vacuum Lifting Attachment which has a suction pump;
- Turbine Vacuum Lifting Attachment - a machine comprising of a rotor with one or more shaped blades which when rotated will cause suction and this in turn creates a vacuum in the vacuum pad;
- Venturi Vacuum Lifting Attachment - air under pressure flows through a constricted section of pipe, the air velocity increases through the constriction and its pressure drops creating a partial vacuum which can be piped to a vacuum pad.

Self-induced (non-powered) vacuum lifting attachments

18. This method of lifting is based on the simple 'suction pad' principle, where an inverted cup-shaped piece of rubber is pushed onto a suitable surface, expelling the air from beneath the cup. Atmospheric pressure on the underside of the surface will then hold the cup in place against a considerable vertical load. The vacuum can be broken by allowing air to enter the evacuated volume under the cup. In the simplest form, the rubber cup with its handle and release valve can hold loads of up to about 35 kilograms. These are usually manual handling devices and are not within the scope of EN 13155

19. Self-induced vacuum systems can be used for greater loads where the rubber cup is replaced by a metal cylinder with a flexible seal around its open end. Above the seal and within this cylinder is a piston, the top surface of which carries a ring for attaching to a crane hook. On lowering this device on to the surface of a load to be lifted, its own weight depresses the seal and the downward movement of the piston expels the air from the cylinder. On lifting, the piston is pulled upwards generating a vacuum within the space formed between the cylinder with seal and the surface being lifted. For loads with a large surface area, several suction cylinders may be used. Both single and multiple cylinder attachments may have many refinements. A valve can be fitted to allow easier escape of air on the downward stroke of the piston, whilst another valve can enable air to enter the evacuated volume when lifting has been completed so that the attachment can be removed easily. Both these valves can be operated either manually or automatically. Some attachments have an air-operated warning whistle which sounds if the load is too heavy. They should also have indicators to warn of loss of vacuum etc (ref: EN 13155).

Power-operated vacuum lifting attachments

20. Power-operated vacuum lifting attachments can take many forms. The power source, which may be an electric motor or an internal combustion engine, drives a vacuum pump which evacuates a reservoir tank fitted with a vacuum gauge. This reservoir is connected to a suction pad or series of pads, which are similar to the cups referred to above. A control valve is located in the vacuum line between the reservoir and the lifting pad or pads. For maximum efficiency the power pack is located as close as possible to the lifting pads which are normally mounted on a metal frame. This frame can be formed of box sections suitably sealed and utilised as a reservoir. Greater flexibility in use can be introduced by fitting each pad with its own control valve. This enables the operator to select the

required number of pads for any particular size of lift. The control valves are arranged so that the vacuum in the reservoir tank is applied between the pads and the load while lifting, while air is later admitted to the back of the pads to release the load.

21. Some powered attachments are built as self-contained units for attachment to the hook of a crane, while more permanent installations incorporate them into a crane which may be either cab or floor operated. The complete attachment, including power pack, may be integrated with a process machine or flow line with its controls forming part of the main control console.

22. There are some vacuum lifting attachments of the powered type which obtain their vacuum by the use of either a venturi operating from an air line, or from a vacuum blower similar in principle to the domestic vacuum cleaner. The use of this type of equipment should be restricted to low weight and low height lifting applications due to the difficulty of incorporating the safety devices discussed in paras 25-28. There are other ways of providing backup in the event of power failure such as a reserve pressure vessel for venturi and a flywheel mass for turbines. See EN 13155

Supply of Vacuum Lifting Attachments

23. It is recommended that vacuum lifting attachments should be dynamically tested in situ as a complete unit on the surface of the material which they are used to lift. The test should be carried out at the SWL of the assembly and should simulate the maximum acceleration/deceleration forces likely to be met in the particular application.

24. As a general rule the load stated by the manufacturer at which the vacuum attachment will not fail should be 2 x SWL at the minimum vacuum level (i.e. bottom end of the working range / beginning of danger range). The appropriate static proof test for a vacuum lifting attachment is also, as a general rule, equal to twice its SWL. Where vacuum lifting attachments are mounted as an assembly on a lifting beam, recommended proof test values are shown in EN 13155.

25. When a vacuum lifting attachment is powered by a vacuum pump, an audible and visible warning device should be provided to warn the operator and other persons in the vicinity of the lifting operation of any failure of the vacuum pump and lifting operation.

26. Whenever possible, the vacuum lifting attachment should be fitted with a vacuum reservoir of sufficient capacity to allow the load to be retained for at least 5 minutes in the event of the failure of the vacuum pump. A suitable warning device in addition to the reservoir vacuum condition indicator should be fitted, which gives a clearly audible or visible warning to operators and others working in the vicinity when the vacuum in the reservoir is below 80% of the normal working vacuum.

27. Vacuum lifting attachments should be fitted with a large, easily read gauge or gauges which, with the load suspended from the device, gives the operator and others in the vicinity of the lifting operation clear indication of the vacuum condition.

28. Any flexible hose or 'wander leads' should be of the armoured type and should be protected as far as possible from accidental damage. See EN 13155 for the advice warning and protection requirements. Note, there are additional requirements for tilting loads, e.g. glass handling, and areas where persons are exposed and secondary holding devices or redundancy is required.

Periodic in-service inspection and examination (VLA)

Restrictions on use (VLA)

30. Vacuum lifting equipment is unsuitable for circumstances where the load is likely to pass over personnel or where the sudden fall of the load could have dangerous consequences, e.g. the rupture of steam pipes or other services hit by the falling load.

31. Care should be taken to ensure that the materials lifted are those for which the attachment was designed. Particular care should be taken when handling porous materials, which may impair the lifting capacity of the attachment. Thin sheets of flexible material require careful positioning to avoid peeling away from the pad due to excessive overhang. If necessary a multi-pad device should be used. Sliding of inclined sheets across the pads can also occur and unless the attachment is specially designed for the purpose, inclined loads should not be lifted. It is essential to position the pads correctly and it is also essential to wipe all surfaces prior to the lift, as loose materials can cause leaks and have caused loads to drop.

Legislation

32. Under LOLER, vacuum lifting devices that are an integral part of machinery are classed as 'lifting equipment'; those that can be fitted to, and taken off, lifting equipment are considered to be 'accessories for lifting'. 'Lifting equipment' and 'accessories for lifting' are both 'work equipment' in accordance with the Provision and Use of Work Equipment Regulations 1998 (PUWER).

33. Where the equipment is used for work purposes, PUWER and other relevant legislation apply.

34. The key requirements under LOLER and PUWER are set out in HSE guidance (see Further Reading) and on the HSE web pages.
35. Vacuum lifting equipment supplied on the market in the EU must satisfy the relevant Essential Safety Requirements (ESR) of the Machinery Directive 2006/42/EC as implemented in the UK by the Supply of Machinery (Safety) Regulations 2008 (SMSR). Further information is set out in HSE guidance.
36. Lifting accessories (e.g. chains, links shackles etc.), used with Vacuum Lifting Attachments are subject to the Health and Safety at Work etc Act (HSWA) 1974 and LOLER and must therefore be tested and thoroughly examined accordingly.

37. A device or accessory which is integral with a crane is considered to be part of that crane and subject to the LOLER Regulations as applicable to the crane. Also, in addition and for example, during the handling of concrete pipes, vacuum lifting attachments are often attached to the boom of a hydraulic excavator either with the bucket still in position or with the bucket removed. Under these circumstances the excavator is considered to be a crane and the terms of LOLER apply to the excavator.

38. Where vacuum lifting equipment is used on construction sites LOLER applies requiring the load to be adequately secured to prevent danger from slipping or displacement. In applications such as the lifting of industrialised building components which have to be raised high above the ground there is a risk that if the vacuum pump fails and there is significant or rapid leakage, there may not be time to lower the load after the alarm rings. Therefore, for high lift applications, i.e. above 10 metres, safety arms should be used. These arms should be engaged while the load is being lifted or some other effective means should be provided of preventing the load from falling in the event of loss of vacuum (see also para 38).

39. Some vacuum lifting attachments may be "relevant machinery" and others "interchangeable equipment", both will be subject to the Supply of Machinery (Safety) Regulations 2008 (SMSR), as amended.

Standards

The current standards for vacuum lifting equipment include:

- BS EN 13155:2003 - Cranes. Safety. Non-fixed load lifting attachments
- BS EN 14238:2004 Cranes - Manually controlled load manipulating devices.
- BS 7121: Part 1: 2006 – Code of practice for safe use of Cranes

40. All associated structural equipment (e.g. jibs, runways and accessories etc.) are required to comply with the relevant design standards and legislations.

Main hazards

41. The principal hazard associated with the use of vacuum lifting equipment is from falling loads. Persons, plant, equipment, and services in the area of operation could be at risk from being struck by a load which becomes detached from the vacuum suction pads (e.g. due to failure of the vacuum, following loss of power, or due to incorrect application or operation etc).

42. Vacuum lifting devices should not be treated as 'general purpose' lifting equipment as they are designed for particular types of loads and environments. Users should seek advice from the equipment manufacturer on the suitability of an existing device for other new applications.

Risk assessment

43. Employers should carry out a suitable and sufficient assessment of the risks, before new or existing vacuum lifting devices are specified for handling loads. This should consider whether such devices are appropriate and suitable taking into account all the circumstances of the proposed operation. The assessment should be carried out by someone with knowledge of the material handling processes, as well as the capabilities and limitations of this type of lifting equipment. Employees and their safety representatives with first-hand knowledge of the hazards and risks involved should be consulted during risk assessment.

Safe Operating Procedures

44. Safe operating procedures should be prepared and kept readily available for each vacuum lifting equipment.

45. The following safe working practices should be considered for inclusion in any operating procedures for the use of vacuum lifting equipment.

- Use the right equipment and be aware of the limitations of each device e.g. 'lift only one piece of material at a time'.
- Always follow the manufacturer's instructions.
- Do not use vacuum lifting devices to handle loads for which it is not designed.
- Where possible, use vacuum lifting only for handling single items for which it is designed. Fully assess the risk of items being lifted becoming detached. Do not exceed the SWL.
- Ensure that there is good vacuum between the surfaces of the suction pads and the load. Vacuum efficiency could be affected by any damage to the suction pads.
- Prevent unauthorised access into 'lifting zones', especially at automatically controlled processes. Provide operators with safe places of work to ensure that they cannot be struck by displaced loads e.g. guarding.
- Do not transport a vacuum lifted loaded where there is a risk of injury to any person should the load or part of it fall off. All movement of materials should be properly organised and managed to prevent injuries and damage to plant and key services. Travel routes should be clearly defined and maintained.
- Transport loaded vacuum pads at the lowest height possible, where practicable no higher than 1.5m above ground level. Where this is not practicable, other precautions should be considered.
- Prepare arrangements for dealing with emergencies e.g. action to be taken in the event of power/equipment failure, displaced loads, etc.

Training

46. Vacuum Lifting equipment should be operated only by competent persons who have been adequately trained in the safe use of the equipment and the findings of any risk assessment. Training should cover:

- potential dangers from the use of vacuum lifting equipment;
- factors which may cause equipment or lifting operation failure and how to avoid them;
- limitations on the use of the equipment;

- instructions on planning and carrying out safe lifting operations, including safe systems of work;
- specific instructions on safe use issued by the manufacturer/supplier;
- location and operation of the equipment controls;
- scheme for examination, maintenance requirements and system for reporting defects;
- emergency arrangements.

Equipment maintenance

47. The manufacturer's instructions for the regular inspection and maintenance of the vacuum lifting equipment must be followed.

Further Reading

- Safe Use of Lifting Equipment. Lifting Operations and Lifting Equipment Regulations 1998 Approved Code of Practice and guidance L113
- Safe Use of Work Equipment. Provision and Use of Work Equipment Regulations 1998 Approved Code of Practice and guidance L22
- Manual Handling Operations Regulations 1992: Guidance on Regulations L23
- BS EN 13155:2003+A2:2009 Cranes - Safety - Non attached load lifting attachments
- Lifting Equipment Engineers Association (LEEA), Code of Practice for the Safe Use of Lifting Equipment (COPSULE), Section 27 – Vacuum Lifters.