

Industrial cooling tower fans and fin fans Guide for design, maintenance and operation

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1 Introduction

This Publication is a Guide to addressing the best design, maintenance and operational practice of mechanical draught cooling tower fans and fin fans used in air cooled heat exchangers. If fans are neglected until they fail, there is often extensive damage to the housing and danger of pieces of blade being thrown out. As well as causing damage to plant, this type of failure presents an unacceptable risk to the safety of personnel. It is clearly desirable to define and adopt appropriate maintenance procedures.

To assist plant maintenance teams, this Publication also sets out appropriate maintenance practices. It provides a framework for the maintenance routines as well as detailed checklists.

2 Scope

The scope of this publication is a guide that covers mechanical draught cooling tower fans and fin fans as used in industrial air cooled heat exchangers. It excludes small fractional-kilowatt drives provided as part of proprietary equipment, e.g. analysers, laboratory equipment, heating and ventilating systems. The Guide does not cover the structural or pressure equipment aspects of the equipment, other than those that directly impinge on the safe operation of the fan.

The publication frequently recommends 'best practice'. This term is used in the sense adopted by the UK Health & Safety Executive as being a recommendation beyond that which is simply required to meet regulations. For a definition of 'best practice' and 'good practice' see Chapter 4.

3 Guidance

3.1 Description of Mechanical Draught Cooling Towers

Figure 1 shows a typical industrial mechanical draught cooling tower fan in situ. Appendix 1 gives further details of a typical cooling tower fan assembly arrangement.



Figure 1 Typical industrial mechanical draught cooling tower fan

3.1.1 Motor and Drive Shaft

Each cooling tower cell has an electric motor mounted just outside the fan chamber with a horizontal drive shaft taking power to the central fan gearbox. On small towers, a single-piece hollow steel shaft (up to 2.5 m (8 ft) long) may be used. On larger towers, former practice was that intermediate bearings were installed on multi-piece shafts. The intermediate bearings can be a significant source of problems and so best practice is to use a single-piece carbon fibre shaft. Metallic coupling components should be made from stainless steel.

3.1.2 Central Gearbox

The central gearbox is of a worm and wheel design, which reduces the motor drive speed down to the fan speed. The fan hub is mounted directly onto the output shaft of the gearbox. The gearbox is typically oil lubricated, with the oil level maintained via an oil pot mounted outside the flume and connected to the gearbox by a small bore pipe. A gearbox vent line may also be provided, venting adjacent to the oiler. In some cases, external oilers are not used and the oil is added direct to the gearbox when it is off-line. Gearboxes can also be connected to a pure mist or purge mist lubrication system in order to help prevent moisture from entering the gearbox. The lubrication of the gears themselves is either by splash lubrication from the sump, or in some cases an internal oil pump provides pressurised lubrication.

An upgrade for the central gearbox is to fit improved oil sealing – bearing isolators or mechanical seals, to improve on lip seals if this is the default supply from the gearbox manufacturer.

Given the harsh conditions that the gearbox has to operate in, regular inspections are required. Best practice is to put an access walkway from the outside of the flume to the central gearbox. Use of fibreglass open mesh decking and a wooden structure does not affect the air flow in the cooling cell.

The gearbox should be supplied to a recognised international standard (e.g. CTI STD-111 or AGMA 420.04) and should have a service factor of 2.

3.1.3 Fan Blade Materials

3.1.3.1 GRP Blades

GRP blades have been in use for many years and are now recommended for new applications. They offer higher efficiency than aluminium blades, do not suffer from corrosion and have given good service. The blades typically have plain ends and are clamped into the hub with aluminium mounting locks secured by means of U-bolts.

3.1.3.2 Solid Aluminium Blades

Cast aluminium blades are typically manufactured in LM4 alloy. Blades up to about 4.3 m (14 ft) diameter are screwed into the hubs with a very fine thread. The female hub threads are split and clamped onto the blade stubs after setting the blade angles. Longer blades have plain ends which are clamped into rubber mounting bushes. These blades are heavy and fatigue failures near the hub have occurred whilst in service. In some cases, blade failures have been caused when the blade has caught the fan cowl. If a single blade failure occurs, other blades often fail due to the out-of-balance condition. On some occasions, blades have been ejected into neighbouring cells causing further failures or ejected from the cooling tower/fin fan altogether with the consequent risk to personnel.

3.1.3.3 Hollow Aluminium Blades

Cooling tower blades can be made from interlocking hollow aluminium sections bolted to an aluminium spar that reinforces the blade near the central hub. In one known application, these blades suffered significant corrosion after two years in service, which then led to fatigue cracks and blade failure. This design of blade is not recommended for cooling tower service.

3.1.3.4 Wooden Blades

Wooden blades were supplied historically, but are not normally used in modern designs.

3.1.4 Guarding

The flume effectively provides the guard for the cooling tower cell, besides the small guard at the drive motor. Guarding design should where possible retain the fan blades in the event of their failure. Given the variety of fan blade and cooling tower arrangements, complete containment cannot be certain, but where practical guarding options that contain the fan blades are available, and best practice is to use these.

Guarding at the motor/drive shaft external to the cooling tower cell must be in compliance with PUWER98 (S.I.2306)

3.1.5 Fan Condition Monitoring and Protection

Best practice is to fit a high vibration trip ("earthquake" seismic switch) to detect severe mechanical problems and ensure the safe shut down of the fan. These trips are normally mounted on the motor support steelwork outside the flume. For routine condition monitoring, an accelerometer should be fitted to the gearbox with an extension wire leading to a socket near the drive motor. This installation permits routine vibration monitoring of the gearbox with the fan running. In addition routine monitoring of the external drive motor would normally be carried out. Such routine monitoring enables planned overhaul of the equipment reducing downtime and the cost of repair.

3.2 Description of Fin Fans

3.2.1 General Description

A fin fan unit is an axial air fan which provides a flow of air over a dry finned tube bank. The tube bank is normally horizontal with the fan mounted just beneath it blowing air up through it, although other layouts do occur. For smaller fans, the fan is mounted directly onto the motor shaft. Larger fans require slower rotational speeds and so are typically mounted in their own bearings with a reducing belt drive from an electric motor. A typical fin fan unit is shown in Figure 2.



Figure 2 Typical fin fan unit

3.2.2 Fan Drive Belts

The older style of fan drive belt arrangement is to have multiple V-belts. These belts are suited to heavier fan blades as they allow some slippage during start up. When lighter fan blades are used, higher efficiency toothed belts can be used. Drive belts need to be of the non-static type for use in flammable material zoned areas (to ISO 1813:2014 or ISO 9563:2015), Low Noise type. Parallel toothed belts can be difficult to align, which can lead to tracking drift and premature belt wear.

Proprietary belt tensioning systems are available and have been used with success on fin fan applications. Typically these consist of a moveable carriage that the motor is mounted on that enables the motor to be moved to achieve the correct belt tension.

3.2.3 Fan Drive Shaft Mounting

The fan is normally mounted on a shaft with grease lubricated bearings and connected to the plenum chamber with a number of struts.

3.2.4 Fan Blades

The blade choices can be the same as for the mechanical draught cooling tower. However, since there are no water droplet or corrosion problems, a further option is to fit lightweight aluminium blades of sheet metal/riveted construction. This design is the preferred construction, as the blades are so light that they are unlikely to cause consequential damage in the event of failure. Their light weight also reduces the load on the bearings and structure of the fan unit.

3.2.5 Guarding

For fin fans where a light (aluminium sheet metal) section fan blade is used, best practice is to have guards that will retain the blades in the event of their failure. Where a heavier section fan blade is fitted, advice should be sought from the fan manufacturer who can sometimes supply heavier or additional guards that have a higher chance of retaining the fan blades in the event of failure. Best practice is to fit such additional guarding. The minimum level of protection is to ensure that the equipment is appropriately guarded to ensure that people cannot be caught in moving machinery.

3.2.6 Fan Condition Monitoring and Protection

Fin fans fitted with light blades (hollow aluminium construction) offer the advantage that blade failures are normally contained within the plenum chamber and so fan shutdown protection is not normally required. An assessment should be made of the fan, based on its blade design, power and its criticality to plant operations, which should determine the level of monitoring. The most basic level of monitoring is to have a running and static visual inspection. For motor powers above 5 kW with heavy fan blades, or if the duty is critical, a routine vibration reading should be taken on the motor and the fan bearing assembly. If the motor or fan bearing assembly is inaccessible, an accelerometer should be fitted such that routine vibration readings can be taken with the fan running. Uncontrolled bearing failure of the fan or motor bearing could give rise to an unacceptable safety problem, as well as causing an expensive and long duration repair.

3.3 Modes of Mechanical Failure

3.3.1 Corrosion Related Failures

Cooling tower fan assemblies inevitably operate in a wet, warm environment which presents a high risk of corrosion, which may be worsened by chemical contamination of the water. Fin fan banks, although not subject to the same moist conditions, are still exposed to atmospheric moisture and corrosion, so similar problems arise, albeit over a longer time.

Failure modes are:

- corrosion and corrosion fatigue of carbon steel fasteners. Fasteners in these systems include coupling bolts, bearing plumber block bolts, guard securing bolts, blade clamping bolts and gearbox securing bolts. Corrosion related failures of bolts in all these locations have serious consequences. A frequently reported failure mode is corrosion fatigue of drive shaft coupling bolts causing the shaft to be thrown into the rotating blades;
- corrosion of the thin walled steel drive shafts, leading to their eventual failure, usually near to the couplings;
- corrosion fatigue of the fine threads on aluminium blades where they screw into the hubs, leading eventually to a blade being thrown out of the hub. The resultant out-of-balance forces may cause further blade failures;
- rotting of timber blades caused by water ingress through defects in the protective coating;
- corrosion of the support structure or the fan cowl. In the case of the support structure, the fan blades can touch the cowl and suffer a rapid fatigue failure at the hub;
- corrosion or attachment failure of the sealing strip between fin fan banks. The sealing strip then falls and catches the fan blades that then fail due to fatigue;