# = Air well ( condenser ) =

An air well or aerial well is a structure or device that collects water by promoting the condensation of moisture from air . Designs for air wells are many and varied , but the simplest designs are completely passive , require no external energy source and have few , if any , moving parts .
Three principal designs are used for air wells , designated as high mass , radiative , and active :
High @-@ mass air wells : used in the early 20th century , but the approach failed .
Low @-@ mass , radiative collectors : Developed in the late 20th century onwards , proved to be much more successful .
Active collectors : these collect water in the same way as a dehumidifier ; although the designs work well , they require an energy source , making them uneconomical except in special circumstances . New , innovative designs seek to minimise the energy requirements of active condensers or make use of renewable energy resources .

## = = Background = =

All air well designs incorporate a substrate with a temperature sufficiently low so that dew forms . Dew is a form of precipitation that occurs naturally when atmospheric water vapour condenses onto a substrate . It is distinct from fog , in that fog is made of droplets of water that condense around particles in the air . Condensation releases latent heat which must be dissipated in order for water collection to continue .
An air well requires moisture from the air . Everywhere on Earth , even in deserts , the surrounding atmosphere contains at least some water . According to Beysens and Milimouk : " The atmosphere contains 12 @,@ 900 cubic kilometres ( 3 @,@ 100 cu mi ) of fresh water , composed of 98 percent water vapour and 2 percent condensed water ( clouds ) : a figure comparable to the renewable liquid water resources of inhabited lands ( 12 @,@ 500 km3 ) . " The quantity of water vapour contained within the air is commonly reported as a relative humidity , and this depends on temperature ? warmer air can contain more water vapour than cooler air . When air is cooled to the dew point , it becomes saturated , and moisture will condense on a suitable surface . For instance , the dew temperature of air at 20 ° C ( 68 ° F ) and 80 percent relative humidity is 16 ° C ( 61 ° F ) . The dew temperature falls to 9 ° C ( 48 ° F ) if the relative humidity is 50 percent .
A related , but quite distinct , technique of obtaining atmospheric moisture is the fog fence .
An air well should not be confused with a dew pond . A dew pond is an artificial pond intended for watering livestock . The name dew pond ( sometimes cloud pond or mist pond ) derives from the widely held belief that the pond was filled by moisture from the air . In fact , dew ponds are primarily filled by rainwater .
A stone mulch can significantly increase crop yields in arid areas . This is most notably the case in the Canary Islands : on the island of Lanzarote there is about 140 millimetres ( 5 @.@ 5 in ) of rain each year and there are no permanent rivers . Despite this , substantial crops can be grown by using a mulch of volcanic stones , a trick discovered after volcanic eruptions in 1730 . Some credit the stone mulch with promoting dew ; although the idea has inspired some thinkers , it seems unlikely that the effect is significant . Rather , plants are able to absorb dew directly from their leaves , and the main benefit of a stone mulch is to reduce water loss from the soil and to eliminate competition from weeds .

## = = History = =

Beginning in the early 20th century , a number of inventors experimented with high @-@ mass collectors . Notable investigators were the Russian engineer Friedrich Zibold ( sometimes given as Friedrich Siebold ) , the French bioclimatologist Leon Chaptal , the German @-@ Australian researcher Wolf Klaphake and the Belgian inventor Achille Knapen .

### = = = Zibold 's collector = = =

In 1900 , near the site of the ancient Byzantine city of Theodosia , thirteen large piles of stones were discovered by Zibold who was a forester and engineer in charge of this area . Each stone pile covered just over 900 square metres ( 9 @,@ 700 sq ft ) and was about 10 metres ( 33 ft ) tall . The finds were associated with the remains of 75 @-@ millimetre diameter ( 3 @.@ 0 in ) terracotta pipes that apparently led to wells and fountains in the city . Zibold concluded that the stacks of stone were condensers that supplied Theodosia with water ; and calculated that each air well produced more than 55 @,@ 400 litres ( 12 @,@ 200 imp gal ; 14 @,@ 600 US gal ) each day .

To verify his hypothesis Zibold constructed a stone @-@ pile condenser at an altitude of 288 metres ( 945 ft ) on mount Tepe @-@ Oba near the ancient site of Theodosia . Zibold ? s condenser was surrounded by a wall 1 metre ( 3 ft 3 in ) high , 20 metres ( 66 ft ) wide , around a bowl @-@ shaped collection area with drainage . He used sea stones 10 ? 40 centimetres ( 3 @.@ 9 ? 15 @.@ 7 in ) in diameter piled 6 metres ( 20 ft ) high in a truncated cone that was 8 metres ( 26 ft ) in diameter across the top . The shape of the stone pile allowed a good air flow with only minimal thermal contact between the stones .

Zibold 's condenser began to operate in 1912 with a maximum daily production that was later estimated to have been 360 litres ( 79 imp gal ; 95 US gal ) ? Zibold made no public record of his results at the time . The base developed leaks that forced the experiment to end in 1915 and the site was partially dismantled before being abandoned . ( The site was rediscovered in 1993 and cleaned up . ) Zibold 's condenser was approximately the same size as the ancient stone piles that had been found , and although the yield was very much less than the yield Zibold had calculated for the original structures , the experiment was an inspiration for later developers .

= = = Chaptal 's collector = = =

Inspired by Zibold 's work , Chaptal built a small air well near Montpellier in 1929 . Chaptal 's condenser was a pyramidal concrete structure 3 metres ( 9 @.@ 8 ft ) square and 2 @.@ 5 metres ( 8 ft 2 in ) high , it was filled with 8 cubic metres ( 280 cu ft ) of limestone pieces being about 7 @.@ 5 centimetres ( 3 @.@ 0 in ) in diameter . Small vent holes ringed the top and bottom of the pyramid . These holes could be closed or opened as required to control the flow of air . The structure was allowed to cool during the night , and then warm moist air was let in during the day . Dew formed on the limestone pieces and collected in a reservoir below ground level . The amount of water obtained varied from 1 litre ( 0 @.@ 22 imp gal ; 0 @.@ 26 US gal ) to 2 @.@ 5 litres ( 0 @.@ 55 imp gal ; 0 @.@ 66 US gal ) per day depending on the atmospheric conditions .

Chaptal did not consider his experiment a success . When he retired in 1946 , he put the condenser out of order , possibly because he did not want to leave an improper installation to mislead those who might later continue studies on air wells .

= = = Klaphake 's collectors = = =

Wolf Klaphake was a successful chemist working in Berlin during the 1920s and 1930s . During that time , he tested several forms of air wells in Yugoslavia and on Vis Island in the Adriatic Sea . Klaphake 's work was inspired by Zibold and by the works of Maimonides , a known Jewish scholar who wrote in Arabic about 1 @,@ 000 years ago and who mentioned the use of water condensers in Palestine .

Klaphake experimented with a very simple design : an area of mountain slope was cleared and smoothed with a watertight surface . It was shaded by a simple canopy supported by pillars or ridges . The sides of the structure were closed , but the top and bottom edges were left open . At night the mountain slope would cool , and in the day moisture would collect on and run down the smoothed surface . Although the system apparently worked , it was expensive , and Klaphake finally adopted a more compact design based on a masonry structure . This design was a sugarloaf @-@ shaped building , about 15 metres ( 49 ft ) high , with walls at least 2 metres ( 6 ft 7 in ) thick , with holes on the top and at the bottom . The outer wall was made of concrete to give a high thermal capacity ,

and the inner surface was made of a porous material such as sandstone . According to Klaphake :
Traces of Klaphake 's condensers have been tentatively identified .
In 1935 , Wolf Klaphake and his wife Maria emigrated to Australia . The Klaphakes ' decision to emigrate was probably primarily the result of Maria 's encounters with Nazi authorities ; their decision to settle in Australia ( rather than , say , in Britain ) was influenced by Wolf 's desire to develop a dew condenser . As a dry continent , Australia was likely to need alternative sources of fresh water , and the Premier of South Australia , whom he had met in London , had expressed an interest . Klaphake made a specific proposal for a condenser at the small town of Cook , where there was no supply of potable water . At Cook , the railway company had previously installed a large coal @-@ powered active condenser , but it was prohibitively expensive to run , and it was cheaper to simply transport water . However , the Australian government turned down Klaphake 's proposal , and he lost interest in the project .

= = = Knapen 's aerial well = = =

Knapen , who had previously worked on systems for removing moisture from buildings , was in turn inspired by Chaptal 's work and he set about building an ambitiously large puits aerien ( aerial well ) on a 180 metres ( 590 ft ) high hill at Trans @-@ en @-@ Provence in France . Beginning in 1930 , Knapen 's dew tower took 18 months to build ; it still stands today , albeit in dilapidated condition . At the time of its construction , the condenser excited some public interest .
The tower is 14 metres ( 46 ft ) high and has massive masonry walls about 3 metres ( 9 @.@ 8 ft ) thick with a number of apertures to let in air . Inside there is a massive column made of concrete . At night , the whole structure is allowed to cool , and during the day warm moist air enters the structure via the high apertures , cools , descends , and leaves the building by the lower apertures . Knapen ? s intention was that water should condense on the cool inner column . In keeping with Chaptal ? s finding that the condensing surface must be rough and the surface tension must be sufficiently low that the condensed water can drip , the central column 's outer surface was studded with projecting plates of slate . The slates were placed nearly vertically to encourage dripping down to a collecting basin at the bottom of the structure . Unfortunately , the aerial well never achieved anything like its hoped @-@ for performance and produced no more than a few litres of water each day .

= = = International Organisation for Dew Utilization = = =

By the end of the twentieth century , the mechanics of how dew condenses were much better understood . The key insight was that low @-@ mass collectors which rapidly lose heat by radiation perform best . A number of researchers worked on this method . In the early 1960s , dew condensers made from sheets of polyethylene supported on a simple frame resembling a ridge tent were used in Israel to irrigate plants . Saplings supplied with dew and very slight rainfall from these collectors survived much better than the control group planted without such aids ? they all dried up over the summer . In 1986 in New Mexico condensers made of a special foil produced sufficient water to supply young saplings .
In 1992 a party of French academics attended a condensed matter conference in Ukraine where physicist Daniel Beysens introduced them to the story of how ancient Theodosia was supplied with water from dew condensers . They were sufficiently intrigued that in 1993 they went to see for themselves . They concluded that the mounds that Zibold identified as dew condensers were in fact ancient burial mounds ( a part of the necropolis of antic Theodosia ) and that the pipes were medieval in origin and not associated with the mounds . They found the remains of Zibold 's condenser , which they tidied up and examined closely . Zibold 's condenser had apparently performed reasonably well , but in fact his exact results are not at all clear , and it is possible that the collector was intercepting fog , which added significantly to the yield . If Zibold 's condenser worked at all , this was probably due to fact that a few stones near the surface of the mound were able to lose heat at night while being thermally isolated from the ground ; however , it could never have produced the yield that Zibold envisaged .

Fired with enthusiasm , the party returned to France and set up the International Organisation for Dew Utilization ( OPUR ) , with the specific objective of making dew available as an alternative source of water .
OPUR began a study of dew condensation under laboratory conditions ; they developed a special hydrophobic film and experimented with trial installations , including a 30 square metres ( 320 sq ft ) collector in Corsica . Vital insights included the idea that the mass of the condensing surface should be as low as possible so that it cannot easily retain heat , that it should be protected from unwanted thermal radiation by a layer of insulation , and that it should be hydrophobic , so as to shed condensed moisture readily .
By the time they were ready for their first practical installation , they heard that one of their members , Girja Sharan , had obtained a grant to construct a dew condenser in Kothara , India . In April 2001 , Sharan had incidentally noticed substantial condensation on the roof of a cottage at Toran Beach Resort in the arid coastal region of Kutch , where he was briefly staying . The following year , he investigated the phenomenon more closely and interviewed local people . Financed by the Gujarat Energy Development Agency and the World Bank , Sharan and his team went on to develop passive , radiative condensers for use in the arid coastal region of Kutch . Active commercialisation began in 2006 .
Sharan tested a wide range of materials and got good results from galvanised iron and aluminium sheets , but found that sheets of the special plastic developed by the OPUR just 400 micrometres ( 0 @.@ 016 in ) thick generally worked even better than the metal sheets and were less expensive . The plastic film , known as OPUR foil , is hydrophilic and is made from polyethylene mixed with titanium dioxide and barium sulphate .

= = Types = =

There are three principal approaches to the design of the heat sinks that collect the moisture in air wells : high mass , radiative and active . Early in the twentieth century , there was interest in high @-@ mass air wells , but despite much experimentation including the construction of massive structures , this approach proved to be a failure .
From the late twentieth century onwards , there has been much investigation of low @-@ mass , radiative collectors ; these have proved to be much more successful .

= = = High @-@ mass = = =

The high @-@ mass air well design attempts to cool a large mass of masonry with cool nighttime air entering the structure due to breezes or natural convection . In the day , the warmth of the sun results in increased atmospheric humidity . When moist daytime air enters the air well , it condenses on the presumably cool masonry . None of the high @-@ mass collectors performed well , Knapen 's aerial well being a particularly conspicuous example .
The problem with the high @-@ mass collectors was that they could not get rid of sufficient heat during the night ? despite design features intended to ensure that this would happen . While some thinkers have believed that Zibold might have been correct after all , an article in Journal of Arid Environments discusses why high @-@ mass condenser designs of this type cannot yield useful amounts of water :
Although ancient air wells are mentioned in some sources , there is scant evidence for them , and persistent belief in their existence has the character of a modern myth .

= = = Radiative = = =

A radiative air well is designed to cool a substrate by radiating heat to the night sky . The substrate has a low mass so that it cannot hold onto heat , and it is thermally isolated from any mass , including the ground . A typical radiative collector presents a condensing surface at an angle of 30 ° from the horizontal . The condensing surface is backed by a thick layer of insulating material such as polystyrene foam and supported 2 ? 3 metres ( 7 ? 10 ft ) above ground level . Such condensers may be conveniently installed on the ridge roofs of low buildings or supported by a simple frame . Although other heights do not typically work quite so well , it may be less expensive or more convenient to mount a collector near to ground level or on a two @-@ storey building .

The 600 square metres ( 6 @,@ 500 sq ft ) radiative condenser illustrated near the start of this article is built near the ground . In the area of north @-@ west India where it is installed dew occurs for 8 months a year , and the installation collects about 15 millimetres ( 0 @.@ 59 in ) of dew water over the season with nearly 100 dew @-@ nights . In a year it provides a total of about 9 @,@ 000 litres ( 2 @,@ 000 imp gal ; 2 @,@ 400 US gal ) of potable water for the school which owns and operates the site .

Although flat designs have the benefit of simplicity , other designs such as inverted pyramids and cones can be significantly more effective . This is probably because the designs shield the condensing surfaces from unwanted heat radiated by the lower atmosphere , and , being symmetrical , they are not sensitive to wind direction .

New materials may make even better collectors . One such material is inspired by the Namib Desert beetle , which survives only on the moisture it extracts from the atmosphere . It has been found that its back is coated with microscopic projections : the peaks are hydrophilic and the troughs are hydrophobic . Researchers at the Massachusetts Institute of Technology have emulated this capability by creating a textured surface that combines alternating hydrophobic and hydrophilic materials .

= = = Active = = =

Active atmospheric water collectors have been in use since the commercialisation of mechanical refrigeration . Essentially , all that is required is to cool a heat exchanger below the dew point , and water will be produced . Such water production may take place as a by @-@ product , possibly unwanted , of dehumidification . The air conditioning system of the Burj Khalifa in Dubai , for example , produces an estimated 15 million US gallons ( 57 @,@ 000 m3 ) of water each year that is used for irrigating the tower 's landscape plantings .

Because mechanical refrigeration is energy intensive , active collectors are typically restricted to places where there is no supply of water that can be desalinated or purified at a lower cost and that are sufficiently far from a supply of fresh water to make transport uneconomical . Such circumstances are uncommon , and even then large installations such as that tried in the 1930s at Cook in South Australia failed because of the cost of running the installation ? it was cheaper to transport water over large distances .

In the case of small installations , convenience may outweigh cost . There is a wide range of small machines designed to be used in offices that produce a few litres of drinking water from the atmosphere . However , there are circumstances where there really is no source of water other than the atmosphere . For example , in the 1930s , American designers added condenser systems to airships ? in this case the air was that emitted by the exhaust of the engines , and so it contained additional water as a product of combustion . The moisture was collected and used as additional ballast to compensate for the loss of weight as fuel was consumed . By collecting ballast in this way , the airship 's buoyancy could be kept relatively constant without having to release helium gas , which was both expensive and in limited supply .

More recently , on the International Space Station , the Zvezda module includes a humidity control system . The water it collects is usually used to supply the Elektron system that electrolyses water into hydrogen and oxygen , but it can be used for drinking in an emergency .

There are a number of designs that minimise the energy requirements of active condensers :

One method is to use the ground as a heat sink by drawing air through underground pipes . This is often done to provide a source of cool air for a building by means of a ground @-@ coupled heat exchanger ( also known as Earth tubes ) , wherein condensation is typically regarded as a significant problem . A major problem with such designs is that the underground tubes are subject to contamination and difficult to keep clean . Designs of this type require air to be drawn through the pipes by a fan , but the power required may be provided ( or supplemented ) by a wind turbine .

Cold seawater is used in the Seawater Greenhouse to both cool and humidify the interior of greenhouse @-@ like structure . The cooling can be so effective that not only do the plants inside benefit from reduced transpiration , but dew collects on the outside of the structure and can easily be collected by gutters .

Another type of atmospheric water collector makes use of desiccants which adsorb atmospheric water at ambient temperature , this makes it possible to extract moisture even when the relative humidity is as low as 14 percent . Systems of this sort have proved to be very useful as emergency supplies of safe drinking water . For regeneration , the desiccant needs to be heated . In some designs regeneration energy is supplied by the sun ; air is ventilated at night over a bed of desiccants that adsorb the water vapour . During the day , the premises are closed , the greenhouse effect increases the temperature , and , as in solar desalination pools , the water vapour is partially desorbed , condenses on a cold part and is collected .

A French company has recently designed a small wind turbine that uses a 30 kW electric generator to power an onboard mechanical refrigeration system to condense water .