增压空冷器使用维护说明书

Charge Air Cooler
Operation and Maintenance Manual

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1. 概要

基伊埃增压空冷器是一种管片式热交换器。其工作原理是:高温增压空气流散经散热片，将热量通过对流作用传递给冷却管外壁，然后经过壁的导热作用传给管内壁，再由管内水的对流作用把热量带走，以完成换热过程。

空冷器传热元件有:椭圆管方片、圆管圆片及圆管方片等几种结构形式。管与片的连接方式通常有:钎焊式、整体轧制式和机械胀接式。

冷却管由胀管器将其两端紧紧地胀接到管板上。侧板作为空冷器的一部分，与管板用螺栓连接紧固。

端盖（即进出水端盖和回流水端盖），作为循环水室，按设计的水流程数设置隔水筋。端盖上装有旋塞用于空冷器的放气和排水。端盖与管板间装有密封垫并用螺栓将其紧固。

端盖、管板和冷却管的材质是根据冷却水质和设计水流速来选择的。

增压空冷器安装在涡轮增压器和柴油机进气总管之间的风道中。其安装形式有两种：

1、空冷器可直接装在风道中（固定式空冷器），这时把空冷器的侧板和管板直接用螺栓安装到风道上，形成风道的一部分。

2、空冷器先装进箱体，然后把箱体用螺栓安装到风道上（可拆式空冷器）。用此法安装，在拆卸维修空冷器时可以不拆卸风道。

2. 固定式空冷器

2.1 概 述

固定式空冷器“Block Cooler”直接安装在发动机的风道中，正如第1部分所述，空冷器的侧板和管板用螺栓直接固定在风道中相应的位置上。

“固定式空冷器”有两种结构形式，即单回路和双回路。回路数即指流过空冷器冷却水的循环水回路数。

双回路空冷器有两个互不相通的循环水回路，各水路有其不同的目的。

2.2 空冷器的安装和拆卸

在安装空冷器前，应先拆卸下进、出气侧和水管连接法兰上的罩盖物；并用松香水洗去用于保护气侧和水侧密封面的保护物。

空冷器既可以直接安装在发动机上，也可以悬置安装在风道中。空冷器气侧连接孔与风道连接孔用螺栓联接坚固，同时加装发动机供应商提供的密封材料。

空冷器进出水法兰与冷却水管用螺栓联接坚固，同时加装发动机供应商提供的密封材料。

为避免空冷器在安装过程中变形和产生应力，所有的连接面都保持平行，被连接面之间的密封须满足设计文件中规定的气密和水密要求。

拆卸固定式空冷器时要按下列程序进行:

1. 排干冷却水
2. 用适当的升降装置支撑住空冷器
3. 拆开进出水管
4. 拆开气侧连接风罩，卸下空冷器。

安装时要使用如前所述新垫片。

拧紧力矩（Nm）

适用于标准公制螺纹、强度等级为8.8级的镀锌螺栓。

规格	螺纹及头加油润滑	加防松止退垫片
M6	9.5	11
M8	21	25
M10	42	50
M12	75	90
M16	180	220
M20	360	430

3. 可拆式空冷器

3.1 概　述

“可拆式管组空冷器（Removable Stack Cooler）”即可拆卸的管组连同其外壳一起安装到发动机的风道中。正如第1部分所述，用螺栓将空冷器的箱体固定在风道中，再把管组慢慢滑进箱体。用螺栓将管组上大管板（固定管板）固定在箱体上并加装垫片以气密。活动管板是通过一个O型橡胶圈和一个长方形密封法兰而形成密封。

要注意，所有的螺栓连接点都必须是气密的。

可拆式管组空冷器可设计为:单回路、多回路和多级空冷器。

回路数是指通过空冷器中水的回路数。双回路空冷器有两个互不相通的循环水回路，各水路有其不同的目的。例如，高温水回路用于发动机缸套冷却，低温水回路用于油的预热。

多回路空冷器可设计为整体管板式。如有必要的话也可以在活动端配置非整体的管板，以适用于微差膨胀。

多级空冷器由多组管组组成，这些管组都安装进同一个箱体内。

多级空冷器的级数是指串联在一个水回路的管组数，故级数不一定与回路数相同。

3.2 空冷器的安装和拆卸

在安装空冷器前，应先拆下进、出气侧和水管连接法兰上的罩盖物；并用松香水或其它非腐蚀性清洗剂清洗去用于保护气侧和水侧密封面的保护物。

空冷器既可以直接安装在发动机上，也可以悬置安装在风道中。空冷器气侧连接孔与风道连接孔用螺栓联接坚固，同时加装发动机供应商提供的密封材料。

空冷器进出水法兰与冷却水管用螺栓联接坚固，同时加装发动机供货商提供的密封材料。

为避免空冷器在安装过程中变形和产生应力，所有的连接面都保持平行，被连接面之间的密封须满足设计文件中规定的气密和水密要求。

运输吊耳是用来提吊和搬运空冷器的，在管组侧板上也焊有起吊耳。

将空冷器箱体安装进风道之前，可先将管组拆下来。拆卸方法是：拧下固定管板与箱体联接的螺栓，并拆下密封填料或活动管板上的盖板。在管组的固定端的端盖上钻有螺纹孔，该螺纹孔是用来方便拆卸螺栓和起盖用的。

箱体安装好后，用螺栓把管组的固定管板紧固到箱体上（加装新垫片），再安装密封填料或罩盖。

安装完毕后若要拆卸管组，可先将固定管板上的螺栓拧下，将活动端的密封填料或盖板，以及冷却水管卸下来（如有发动机系统的部件妨碍撤下管组，这

些部件都应拆除）。最后用适当的起吊装置将管组从箱体里抽出来。

为了使管组比较容易地从箱体内抽出，我们固定管板上钻有拆卸螺纹孔（孔径与箱体框架上的螺栓孔相同），该螺纹孔用于起吊和拆卸时安装吊耳或拆卸螺栓。

重新安装时应使用如前所述新密封垫。

4. 试运行

4.1 概　述

基伊埃空冷器在出厂前都进了水压试验，并检验合格。然而，我们还是建议用户在安装前要按标定的测试压力对空冷器进行压力测试。

如果库存期或停用期超出了规定范围，端盖的密封可能会有渗漏现象。这时可通过拧紧螺栓（拧紧力矩见前表）。倘若拧紧螺栓不能解决问题，就应考虑更换新密封垫。更换新密封垫后，要在规定的测试压力下再进行压力测试。

安装完毕后向空冷器内充水以排气，排气时将端盖上的放气塞卸下排气，排气完毕后再将其安装回原处。

空冷器投入使用后，要立即排气数次。把整个冷却系统的空气排出比只排出空冷器的空气效果要好些，因此最好是排出整个冷却系统的空气。

多回路或多级空冷器，每个回路和每级都要单独排气。

整个设备检测无渗漏，并保证冷却水畅流无阻后，空冷器便可投入使用。

在发动机加速到正常负载时，测量空冷器进气和出气温度，并根据性能数据表中的流量要求，调定冷却水达到正常流量。

4.2 冷却水流速

空冷器运行时，参照下表维持冷却水流速。

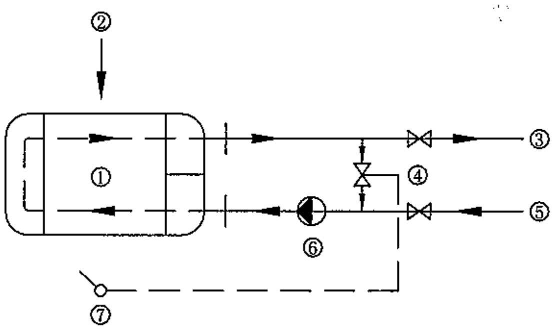
管　材	最小流速	最大流速
CuZn28Sn(SOMS71)	1.0m/s	2.0m/s
CuZn20Al(SOMS76)	1.0m/s	2.2m/s
CuNi30Fe(CuNi70/30)	1.5m/s	3.0m/s
CuNi10Fe(CuNi90/10)	1.5m/s	3.0m/s
Cu/SB or SF	1.0m/s	2.0m/s
Steel	2.0m/s	2.5m/s

空冷器决不能在最小水流速下长期工作，应按性能数据表中标定流量维持空冷器供水。

频繁改变水的流速不利于在空冷器内壁形成保护膜，而保护膜对于防腐蚀是至关重要的。如果水流速太小，容易产生沉积物;如果水流速太大，又容易产生侵蚀。管路的节流或进水口的位置不当，容易在水中产生易造成腐蚀的富氧离子。为了在部分负载的情况下也保持均衡的水流量、流速，就必须安装控制装置。

4.3 冷却水流速的控制

现已证明，下图所示的旁通控制装置能满足控制水流速、流量的要求。旁通装置可以这样设置：即，空冷器的出水端与冷却水泵进水端旁通，由阀门及控制装置来调节空冷器进水的冷热度和流量，以保证增压空气出口温度的衡定。这样就能在各种负荷下使冷却水流量、流速和空冷器出气温度保持在推荐的范围内变动。



旁管控制装置平面图

①增压空冷器

②增压空气进口

③冷却水出口

④流量控制阀

⑤冷却水进口

⑥泵

⑦控制装置

5. 保护膜

确保形成结实、耐久保护膜的方法。

铜及铜合金所固有的耐腐蚀性能就在于：它们能够形成难以溶解的自然保护膜。

千万不要把污水用于未形成良好保护膜的新空冷器中，因为冷却管内表面的沉积附着物，不利于形成上述保护膜。

鉴于上述原因，空冷器进行水压测试时要用洁净的淡水。在试运行期间同样要避免使用污水。

我们建议在试运行期间往水中加入少量易溶的硫酸亚铁（$FeSO_4.7H_2O$），以便确保在可能使用污染水前，管子表面形成良好的保护膜。

在冷却水中加5mg/l硫酸亚铁，并保持每天有1小时的运行就足以形成良好的保护膜。如有可能，在正常运行期间也要反复加入硫酸亚铁，直到第一次进行维修检查。

在靠近空冷器进水口处的管路上安装适当的旁路系统，以用于添加硫酸亚铁。

6. 停用

如果空冷器停用时，整个冷却水系统内的水未排放干净，那么对空冷器由铜、铜合金钢及铸铁等材料的部件来说是有危害的。

在保护膜形成之前，或是在诸如铵化合物和硫化氢等腐蚀性物质有可能沉积侵蚀的情况下，停用对于铜和铜合金来说是特别危险的。

如不能排干空冷器的水，那么在试运行后的头两个月内就尽量不要停止空冷器的运行。

如果由于冷却水供应出了问题导致停用，但停用不超过三天；且以后空冷器便能长期持续运行，那么停用时可以不排干空冷器的水。

一定要确保管内没有发生沉积现象。如果沉积已经发生，那么就要把空冷器的水排放干净后清洗管子， 再用净水冲洗， 然后吹干。我们建议用暖风或预干燥过的空气吹干管道， 空冷器应保持良好通风。

假如冷却水是海水、咸水或盐水（氯化物含量≥500mg/l），那么冲洗就应使用含盐量低的水（饮用水质的水）。

两个月的试运行期内停用空冷器，且停用时间超过三天，为防止发生沉积现象，应排干空冷器的水，然后冲洗并吹干。

两个月的试运行期后停用空冷器，为避免停用造成的腐蚀，每次停用如期限超过两个星期都要按上述的清洗程序进行清洗。

空冷器试运行后的正常运行期间如果要停用空冷器，一定要限制停用期不排水超过三天的停用次数，并按我们建议的在试运行期的条件操作。

如停用期很短， 空冷器可用低水速度来运行， 假如在此条件下能有效防止管内形成沉积的话，用低水速运行要比冷却水滞留在空冷器中好，因为象铵化物和硫化氢等腐蚀成份能被冲走，不积留在管中。

冬季，霜冻会损坏空冷器，所以哪怕是最短暂的停用也要排干空冷器内的水。

7. 运行控制

7.1 概　述

至于运行控制，需要在风道中及空冷器进出水管上安装温度计。我们建议在机器运行记录本上定期记下空气和水的温度。如有特殊要求，可以使用更复杂的控制装置。

如果在空冷器出气侧出现大量冷凝液，通过使用如前所述的冷却水旁管控制装置，来避免产生冷凝水或限制冷凝水的析出量。

必须保证冷凝水能及时排放掉。

7.2 性能试验

基伊埃承诺的性能保证主要是指在正常运行时，冷水和冷空气之间的温差，必须要经常检测。

如在空冷器正常运行时观察到温度比保证温差高，这可能是空冷器中积存空气的原因，可用前文中所述的方法（给空冷器排气）来解决这个问题。

如按上述方法进行处理仍未能改进性能，且又没有发现其它故障的话，这台空冷器就需要清洗了。

可用压差表来检测空冷器的气侧或水侧是否需要清洗。因此我们建议在风道中和空冷器的进出水管上安装压差表。

8. 清 洗

8.1 概述

水侧和气侧热交换面的清洗，对于保障空冷器长期无故障运行是非常必要的。清洗周期要根据空冷器运行方式，冷却水质及吸入空气的物性来决定。

清洗方式有：机械清洗、水力清洗和化学清洗。

8.2 水侧的清洗

水侧清洗需定期进行，其周期由冷却水质来确定。

水侧清洗不仅是为了保持空冷器的热交换性能;也消除冷却管内因结垢造成的腐蚀、或因障碍物造成侵蚀的危险。

8.2.1 机械清洗

机械清洗是通过装在刷杆上的尼龙刷来进行的。

刷杆的长短由冷却水管长度而定。要选择与散热管型号相应的刷子。每台空冷器在发货时都配有带柄的清洗刷。

机械清洗可以在不挪动空冷器的情况下进行，也可以把空冷器拆卸下来进行。在清洗时，至少要卸下一个端盖。为了卸下端盖，我们在端盖上钻有与端盖法兰螺栓直径相等的螺纹孔，用以拆卸端盖之用。管子需要逐根刷洗，冲去污物直到没有一点残留物。清洗完毕后，更换新密封垫并重新装上端盖， 再注人冷却水排气。

8.2.2 水力清洗

水力清洗时要将空冷器卸下进行。用装有特别喷嘴的高压喷枪来清除冷却管内的沉积物。

8.2.3 化学清洗

化学清洗可以在不挪动空冷器的情况下进行，也可以把空冷器拆卸下来进行。

8.2.3.1 不挪动空冷器进行化学清洗

为了确保空冷器运行时管内没有结垢和污物，我们建议安装一个与空冷器配套的连续运行的化学清洗系统。

该清洗系统包括一个循环泵、一个洗涤槽、截流阀

及相应的管路。清洗的水回路联接于冷却器的进出水管路上，该回路位于截流阀与端盖进出水法兰之间。

清洗之前要截断冷却水流，通过空冷器的出水管道将水排干。拧下排气螺塞排水。水排尽后，关闭冷却水阀。打开清洗水管的阀门，启动循环泵。排气完毕后要拧紧排气螺塞。

我们建议清洗水回路的水流方向与工作水回路流向相反。

清洗完毕后，将空冷器里的水排干，空冷器内不能留存清洗剂。关闭清洗水管的阀门，并打开冷却水阀门，用常规的冷却水冲洗。

最后空冷器需重新排气。

化学清洗也可以除去冷却水管道中的水垢沉积物。清除水垢沉积物需要用10%的盐酸加0.5%的抗氧化剂，这样清洗对有些管材特别适用。

清洗完毕后，要彻底冲洗空冷器，做到空冷器中没有一点清洁剂残留物。如果清洗以后空冷器要停用一段时间，这一点就更为重要。

如果对安装好的空冷器进行化学清洗，就不需要卸下端盖。我们建议用适当的工业洗涤剂进行化学清洗。

使用化学品清洗时，一定要按照清洗剂生产厂家提供的说明及用法指南进行。

8.2.3.2 拆下空冷器进行化学清洗

如果空冷器管路上没有安装化学清洗系统；或如果机械清洗和水压清洗都不成功的话；那么就要拆卸下空冷器进行化学清洗。

把端盖拆下后，将空冷器芯组放入洗池内浸泡清洗，浸泡的时间根据积垢程度而定。如果一次清洗效果不理想，那么就应反复清洗。

清洗程序及清洗剂见8.2.3.1条中的说明。

8.3 气侧的清洁

8.3.1 概　述

气侧的清洗应尽早进行，以避免散热片上聚集油烟（这些油烟在一段时间以后就会结一层很难清除的硬壳），以及其它腐蚀性的沉积物。如果这些腐蚀性的沉积物残留在管、片上一段时间以后，其中的一些物质就会与冷凝液化合，形成硫化物造成腐蚀。

8.3.2 水力清洗

空冷器被拆卸下后，用水力清洗是很有效的。在8.2.2节中讲到的高压喷射枪也可用于这一目的。我们建议用3mm喷嘴的喷枪，在距散热片2米处，用60 ~ 80bar的高压水垂直冲洗冷却水管（喷射水流与散热片平行）。

8.3.3 化学清洗

我们建议在空冷器拆卸下来后对空冷器气侧进行化学清洗。

清洗的程序是：拆下端盖后将空冷器管组浸入化学清洗槽中浸泡清洗（浸泡的时间根据积垢的程度而定)，清洗完毕后用高压水枪冲洗空冷器。如效果不理想，那么就应反复清洗。

为了提高清洗槽的清洗效果并缩短清洗时间，我们建议:洗槽内的水应循环流动。也可用喷枪喷射清洗液来清洗。我们建议使用适当的工业洗涤剂对气侧进行清洗。

使用化学品清洗时，一定要按照该清洗剂生产厂家提供的说明及用法指南进行。

9 管漏

9.1 概 述

腐蚀、侵蚀及错误的操作均可以导致管漏。如果发现空冷器渗漏，先必须查出渗漏的管子。如果目测发现不了，可以对空冷器进行压力测试、也可以对每根管子分别进行压力测试，以找出发生渗漏的管子。

9.2 单根管的压力测试

压力测试前要卸下空冷器前后端盖（如果空冷器周围有足够的空间就没有必要卸下空冷器），用管子堵塞将接受测试的管子两端都塞住，其中必须有一个塞子上有空气或水的接头，然后通压力空气或水进行测试。

可以安装压力表来显示压损。施压后即使冷却水管上有很小的渗漏也会很快从表上显示出来。

如果不用压力表来检测空冷器，那么拆卸下空冷器， 以便从散热片侧对渗漏进行目侧。

9.3 空冷器的压力测试

如果我们不拆端盖对空冷器进行水压测试，那么就得用手电筒在散热片侧寻找显示渗漏的湿点。为了避免邻近冷却水管上的湿点影响判断，应该在检测前通过吹风使气侧干燥。

9.4 在水下进行空气压力测试

如果没有安装压力表，那么空冷器压力测试也可在水下进行。我们将空冷器浸没在一个水槽中，在不拆卸端盖的情况下对水侧施加0.5bar的空气压力来测试管子，如果有渗漏就会有气泡冒出来。

但应注意，积聚在散热片上的空气也会产生气泡， 这些气泡并不表明管子渗漏。

9.5 堵管

一旦我们找到了出故障的管子，就应该把管子两端用坚硬的木头，橡胶塞或铜螺塞堵起来（交货时同时提供塞子），不能用钢螺塞，因为钢螺塞会损伤管板孔。所有型号的管子无一例外地都可以堵塞。

如果有几根管子同时渗漏，我们必需现场评估堵管后的空冷器性能是否能满足要求或咨询我们售后服务部门。

9.6 个别管子的更换

如果空冷器是单管片式，即椭圆管方片、或是圆管挤片，这时就可以更换渗漏的管子。如果是在管组中发现了渗漏管，这时要把周边邻近的管子也卸下来更换，以便能够接触到渗漏管。需要更换的管子卸下后，必须清洗管板上的孔。

用来更换的管子一端有一段光管（未装散热片）。更换时，先将管子的光管端插进一块管板的管孔内。然后回拉，再插进另一块管板相应的孔内，最后用胀管器把管子胀到管板上。

9.7 插入另一根芯管

如果是穿片、整体胀接式空冷器，要想更换一根管子是难以办到的。这时如发生渗漏现象，我们可以用直径小于渗漏管，管径合适的管子插入渗漏管中，再外胀把替换管胀接到管板上防止渗漏。

9.8 空冷器修理后的压力测试

空冷器修理完毕后，我们必须按规定的测试压力对空冷器进行压力测试。规定的测试压力标明在空冷器的端盖或箱体上。

修理管漏所需的芯管，工具以及其它材料都可以

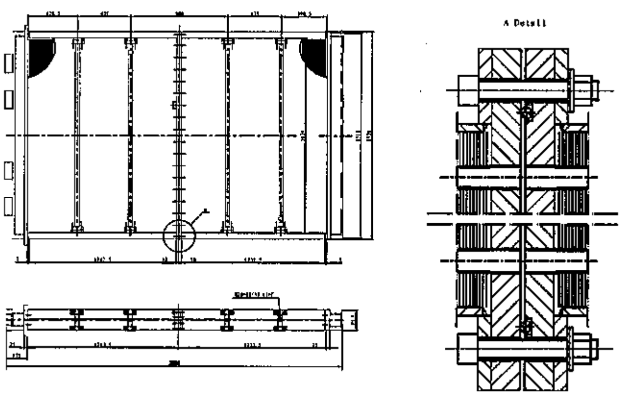
直接向德国基伊埃公司购买，或向基伊埃工业热交换器系统（芜湖）有限公司购买，也可以在我们世界各地的维修中心购买。

10. 预冷级空冷器分解检查

由于预冷级空冷器结构设计的特殊性，它的维修检测方法与主级使用的常规方法相比有所不同。

10.1 预冷级空冷器结构

预冷级的设计想法是为了便于清洗暴露在进气侧面容易污染的表层管片。清洗时只需将预冷级抽出来而不需要将整个空冷器抽出来，预冷级由两部分构成，中间用螺栓将两块管板连接在一起，两管板间用O型圈弹性联结并使管子与外界密封，但不是单根管一一对应贯通的，管板间存在的很小缝隙会使管子之间串水，见图：



10.2 检测管漏的特殊性

10.2.1 空冷器漏水的常规检测方法

常规漏管检测方法是将空冷器两头端盖拆下（空冷器无需整体从箱体中抽出来），采用气压逐根进行检测，具体做法是：封闭管子的一端，在另一端泵气压并使用专业的测量设备检测压力是否稳定，如压力泄漏，则管漏。简易的方法也可以使用水压试验，通过单管泵水并观察是否漏水来查出漏管。

10.2.2 预冷级检测的特殊性

常规的泄漏探测方法对预冷级空冷器不适用，因为中间联结管板之间有一个小的缝隙，由此会产生水的交叉流动。这样就很容易将大部分的管子误判为漏水。

因此在检测预冷级空冷器之前必须将其抽出箱体并且将两个部分分开，按照标准的常规方法独立地进行检测，每个预冷级部分的漏管必须将管子两端都堵住。

10.3 垫片及O型圈的更换

空冷器检测完毕后要将预冷级空冷器重新装配起来，为了预防老化或变形，中间的O型圈需要换新。另外，两头端盖的垫片也需要更换。

1. General

The GEA charge air cooler is a finned tube heat exchanger. The hot air flows through the fins on the outside of the tubes and the cooling fluid flows through the tubes. The heat exchanger surface of the cooler consists of elliptical core tubes with rectangular threaded-on fins or round core tubes with either wound-on fins or continuous flat plate fins. The bond between fin and tube is achieved either by mechanical means or by soldering.

The core tubes are rolled into the tube sheets at each end of the tubes with roller.

Side wall form an integral part of the cooler and are bolted to tube sheets.

Water Headers (Namely connection and Return headers) are provided for water handling. The number of separation baffles conforms to the number of water passes. The headers are bolted to the tube sheets, gaskets interposed to form a seal. Plugs in the header are provided for cooler venting and draining.

The materials for headers, tube, sheets and core tubes are chosen in accordance with the specification of the cooling water to be used and the recommended water velocity in the tubes.

The charge air cooler is mounted in the air duct between the turbo charger and the diesel engine air inlet manifold. Mounting can be done as an integral part of the air duct (block cooler), the cooler side walls and tube sheets being bolted directly to the air duct. As an alternative the cooler can be mounted into casing which in turn is bolted to the air duct (Removable stack cooler), this method enables the cooler to be removed for repairing without dismantling air ducts.

2. Block cooler

2.1 General

The term, " Block cooler" refers to the design: mounted directly into the air duct of the engine. As already explained under part 1, the block cooler is bolted into the air duct at its side walls and tube sheets respectively.

There are two types of block coolers, namely single and double circuit coolers.

The number of circuits corresponds to the number of water flows passing the cooler.

The twin circuit cooler has two separate water flows which are independent from each other.

These two flows can be used for different purposes, i .e. for engine cooling, air or oil preheating etc.

2.2 Installation and removal of the cooler

Prior to installation the cooler, the transport covers at the air opening and the blanks on the water connection flanges are to be removed. The air and water side sealing surfaces, which are protected prior to shipping, must be cleaned with turpentine.

The cooler can either be mounted to the engine as a self supporting unit on a bracket, or alternatively it can be mounted in the air duct as a cantilever unit. The air side connections are bolted to the air ducts using gaskets or sealing compound provided by the engine builder. The cooling water pipes are bolted to connection flanges on the connection header using gaskets also provided by the engine supplier.

To avoid deformation and stresses during installation all connecting surfaces must be parallel and the tolerances should be kept as small as possible.

All connections are to be air and water tight.

When removing the block cooler the following procedure should be used.

1. drain off cooling water.
2. Support cooler with suitable lift ing gear.
3. Disconnect cooling water pipe.
4. Disconnect cooler form air side trunk and remove.

Installation is done by use of new gaskets as described above.

TIGHENING TORQUE (Nm)
FOR GALVANIZED SCREWS WITH CLASS OF STRENGTH8.8
WITH NORMAL METRICAL THREADS.
THREADS AND CONNECTING SURFACES FROM SCREWS
AND NUTS ARE OILED

规格	Fastening torque (thread and head lubriated by oil)	Fastening torque With Nordlock-washers
M6	9.5	11
M8	21	25
M10	42	50
M12	75	90
M16	180	220
M20	360	430

3. Removable stack cooler

3.1 General

The term "Removable stack cooler" refers to a design: where a cooler casing is fit ted with a removable tube stack into the air duct of engine. As already explained under part 1, the cooler casing is bolted into the air duct. The tube stack is slid into the casing. The protruding tube sheet (fixed end) of the tube stack is bol ted to the casing using a gasket to form an air seal. The extension end of tube sheet is seated by means of an rubber O-ring and a sealing frame which form a gland packing. Alternatively a cover plate header is used. All bolt connections are to be air tight.

Removable stack coolers are designed as single-circuit, multi-circuit and multi-stage coolers.

A multi-circuit cooler is designed with common tube sheets and if necessary can have a split tube sheet on the extension side to accommodate differential expansion. A multistage cooler consists of separate tube stacks which are mounted into a common casing.

The number of circuits refers to the water flows through the cooler. The twin-circuit cooler has two water flows which are independent from each other, these two flows can be used for different purposes, i.e. for engine cooling, air or oil preheating etc.

Since the tube stacks can be connected in series on the water side, the number of stages in a multi-stage cooler refers to the number of tube stacks fitted into the common casing, and need not to be ident ical with the number of water flows through the cooler.

3.2 Installation and removal of the cooler

Prior to installation of the cooler, the transport covers of the air side and the blanks on the water connection flanges are to be removed. The air and water side sealing surfaces, which are protected prior to shipping, must be cleaned by the use of turpentine.

The cooler can either be mounted to the engine as a self supporting unit on a bracket, or alternatively it can be mounted in the air duct as a cantilever unit. The air side connections are bolted to the air ducts using gaskets or seal ing compound provided by the engine builder.

The cooling water pipes are bolted to connection flanges on the connect ion header using gaskets also provided by the engine builder.

To avoid deformation and stresses when installing the cooler all connecting surfaces must be parallel and the tolerances should be kept as small as possible.

All connections are to be air and water tight. Transport lugs are provided on the side walls for lift ing and handling of the complete cooler. Lifting lugs are also welded to the tube stack side walls. Prior to installation of the cooler casing into the air duct the tube stack can be removed by means of unscrewing the bol ts holding the protruding tube sheet to the casing frame and removal of the gland packing or cover plate at the extension end tube sheet. At the fixed end of tube stack threads are provided in the water header for eyebolts to be used when lifting and pulling out. When the casing is installed the tube stack is fitted (new gaskets interposed) by bolting the protruding tube sheet to casing frame and mounting of the gland packing or hood. When removing the tube stack after final installation the bolts holding the protruding tube sheet are unscrewed, the extension end gland packing or cover plate and cooling water pipes are removed and the tube stack is pulled out of the casing by the use of suitable lifting gear. To ease breaking the tube sheet from casing frame gasket seal, threaded holes with the same dimension as the bolts used for the casing frame are provided in the protruding tube sheet for jacking screws. The casing bolts may be used for this purpose. Installation is done by use of new gasket as described above.

4. Commissioning

4.1 General

The cooler is subject to a hydraulic pressure test in our factory. It is however recommended to carry out a test with the specified test pressure before installation.

If after prolonged storage or extended standstill the geared gaskets are leaking, tightening of the geared bolts might prevent further leakage. If this is not sufficient the header gaskets must be replaced. A pressure test with specified test pressure should be carried out after replacement.

After assembly of the cooler is completed the cooler is circulated with the specified cooling water quantity prior to venting.

For cooler venting, the vent plugs in the headers are removed. After the air has escaped from the cooler the plugs are fitted again. Venting should be repeated shortly after cooler is taken into operation. Venting of the complete cooling system is better than venting only the cooler and should therefore be preferred.

With multi-circuit or multi-stage coolers, each circuit or stage should be vented separately.

After a leak test has been carried out on all plant components, and the water flow has been checked to ensure there are no restrictions, the cooler can be put into operation.

Upon accelerating the engine to the nominal load the air temperature should be measured before and after the cooler and the cooling water flows set in accordance with the nominal water flows stated in the performance data sheet for the cooler in question.

4.2 Cooling water velocity

The following water velocities should be maintained during operation:

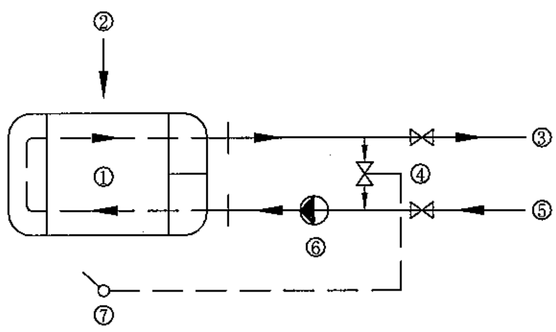
Tube material	Min.	Max.
CuZn28Sn(SOMS71)	1.0m/s	2.0m/s
CuZn20Al(SOMS76)	1.0m/s	2.2m/s
CuNi30Fe(CuNi70/30)	1.5m/s	3.0m/s
CuNi10Fe(CuNi90/10)	1.5m/s	3.0m/s
Cu/SB or SF	1.0m/s	2.0m/s
Steel	2.0m/s	2.5m/s

Never operate at min. Velocity for a prolonged period of time. The nominal water flow stated in the performance data sheet for the cooler in question should be maintained.

Frequent fluctuation of the water velocity impede the formation of a protective film on the tube inside, which are vital for corrosion protection. A too low water velocity encourages dirt deposits and a too high velocity causes erosion. To throttle the water flow or improper position of the water intake could lead to oxygen enriched water which favours corrosion. To keep the water flow, and so the water velocity, constant also during part load operation, control devices should be installed.

4.3 Control of cooling water velocity

The bypass control as shown below has proved suitable for this requirement. Bypassing can be done in such way that the discharged warm cooling water is mixed with the cold water at the suction side of the cooling water pump to assure operation at almost constant charge air outlet temperature. Subsequently water flow, velocity and charge air outlet temperature can be kept within the recommended range at all load conditions.



Layout of a bypass control system

①charge air cooler

②charge air inlet

③Cooling water outlet

④Flow control valve

⑤Cooling water inlet

⑥Pump

⑦Temperature sensor

5. Protection film

Measures to assure the formation of a strong and durable protective film.
The inherent good chemical corrosion-resistance of copper and copper alloys is due to their ability to form a natural protective film which is difficult to dissolve.
New cooler tubes lacking a sufficiently strong protective film should never be operated with contaminated water, as deposits on the material surface would prevent the formation of such a protective film.
For the above reason clean fresh water is used for the hydraulic test of the heat exchanger. The utilization of contaminated water should also be avoided during test runs.
During test runs it is recommended to add small quantity of easily soluble ferrous sulphate ($FeSO_4.7H_2O$) to the cooling water to make sure that a good protective film is formed before operating with contaminated water.
It is sufficient to add about 5mg/l to cooling water during a period of one hour every 24 hours. Adding of ferrous sulphate should, if possible, be repeated during normal operation until the first inspection is carried out.
An appropriate valve for adding ferrous sulphate should be provided in the piping close to the water inlet nozzle of the cooler.

6. Standstill

A standstill of the cooling water system, leaving the cooler undrained, is hazardous for cooler parts made of copper, copper alloys, steel and cast iron.
For copper and copper alloys standstills are especially hazardous prior to the formation of a protective film or in the case that the destruction of the same must be feared for reason of deposit at tacked by putrefact ion products such as ammonium compounds and hydrogen sulphide.
If possible, cooler operation should not be interrupted during the first 2 months after commissioning if the cooler can not be drained.
However, if there is a failure in cooling water supply and operation is resumed within 3 days and then for a prolonged period of time kept uninterrupted, the cooler may be left undrained.
It must be then guaranteed that the tubes are free from deposits. If deposits have formed, the cooler should be drained, the tubes cleaned and flushed with clean water prior to being dried. We recommend the use of warm or pre-dried air for blowing through the tubes. The coolers need to be vented adequately. If sea water, brackish or saline water (chloride content>500mg/l) is used as cooling water, water with low salinity (drinking water quality) should be used for flushing. In case of standstill within the start up period of 2 months which is expected to last for more than 3 days, and where deposits must be feared, the cooler should be drained, flushed and dried.
To avoid standstill corrosion after the first 2 months of operation the above described cleaning procedure should be repeated by every standstill lasting longer than 2 weeks. In case of permanent service interruptions after the start up period it may be necessary to limit the standstill where the cooler is kept undrained to 3 days and operate the unit under conditions as recommended for the start-up period. During short standstill the cooler can be operated at low cooling water velocity so formation of deposits in the tubes can be prevented. Operating with low water velocities is to be preferred to cooling water standstill in the tubes as putrefaction products, such as ammonium compounds and hydrogen sulphide are washed away from their point of origin.
During winter time standstill if frost injury to the cooler could occur the cooler should be drained also during the shortest standstill.

7. Service control

7.1 General

For service control, thermometers are to be installed in the air ducts and in the cooling wate piping before and after the cooler, we recommend to keep record of the air and water temperatures in the machinelog book periodically. Further control instruments can be provided in accordance with the individual requirement.
In case of the occurrence of a major amount of condensate after the cooler, further condensation can be prevented,or at least limited, by the use of a bypass control of the cooling water as previous described.
A possibility to drain the condensate must be assured.

7.2 Performance test

The performance guarantee given by GEA is main expressed by the temperature difference between cold water and cold air during normal operation and should be checked from time to time.
In the event that a considerable increase of the guaranteed temperature difference observed during normal operation, this might be due to accumulation of air in the cooler. To remedy the above the cooler should be ventd by using the procedure previously described.

In case a performance increase cannot be achieved by proceeding as above and provided no other disturbance can be found, the cooler needs cleaning.

A differential pressure gauge can also be used to check whether or not cleaning of the air or water side of the cooler is necessary. We recommend to install differential pressure gauges in the air duct and water piping before and after the cooler.

8. Cleaning

8.1 General

Cleaning of the water and air side heat exchange surfaces is imperative for a long and trouble free operation of the cooler. The cleaning intervals vary with the mode of operation, cooling water quality, intake air characteristics etc.

Cleaning can be done by either mechanical, hydraulical or chemical means.

8.2 Cleaning of the water side

Regular cleaning is necessary. The cleaning intervals depend on the cooling water used. Cleaning of the water side is not only required to maintain the thermal performance of the cooler. Scaling increases the risk of biting corrosion and obstacles partly blocking the tubes favours erosion.

8.2.1 Mechanical cleaning

Mechanical cleaning is done by use of nylon brushes fitted to a rod. The length of the rod corresponds to the tube length of the cooler in question and the type of brush is chosen in accordance with the finned tube type. The brush with rod is part of each cooler delivery.

Mechanical cleaning can be done in-situ or with the cooler removed. At least one header needs to be removed when cleaning. For header removal threaded holes with the same dimension as the header bolts are provided in the header flange to serve as jacking screws. The wet tubes should be thoroughly brushed clean one after the other and the dirt flushed out until no residues are left. After the cleaning is completed the headers are refitted using new gaskets. Venting must be repeated after cooling water is refilled.

8.2.2 Hydraulic cleaning

Hydraulic cleaning is carried out with the cooler removed using a high pressure spray gun with special nozzle to remove dirt deposits inside the tubes.

8.2.3 Chemical cleaning

Chemical cleaning can be carried out in-situ or with the cooler removed.

8.2.3.1 Chemical cleaning -In-situ

To ensure that the cooler is always operated without fouling or scaling in the tubes we recommend an integrated and continuously operating chemical cleaning system to be fitted.

Such cleaning system comprises of a circuiting pump and adetergent tank with the necessary piping and shut off valves. The detergent circuit is connected to the cooling water inlet and outlet piping between their shut off valves and the water header flanges.

Prior to cleaning, the cooling water flow is interrupted to allow the cooler to drain via the cooling water outlet piping. For draining the vent screw are removed. After draining, the cooling water valves are closed. The valves of the cleaning circuit are opened and the circulating pump switched on. The vent screws are fitted after venting completed.

It is recommended to connect the cleaning circuit to the cooling water outlet piping in such a way that the detergent flow is opposite to the normal cooling water flow.

When cleaning completed the cooler is drained leaving no detergent in the cooler. The valves of the cleaning circuit are closed and the cooling water valves opened. Flushing is done with normal cooling water. Reventing of the cooler is necessary.

Scaling deposits in the cooling tubes can be removed by chemical cleaning as well. For removal, a 10% HCL hydrochloric, or muriatic acid is used and a 0.5% inhibitor (specifically suitable for the individual tube material) added.

After cleaning, the cooler is to be flushed thoroughly, i.e. no detergent residues are allowed to be left in the cooler. This is most important in case the cooler is shut down for a short time after cleaning.

If the cooler is chemically cleaned in mounted position the headers need not be dismounted. For chemical cleaning, we recommend to use suitble detergents to clean:

The instructions and handling guidelines provided by the manufacturer of the detergent in question should always be observed when using the chemical.

8.2.3.2 Chemical cleaning -Cooler removed

Chemical cleaning while the cooler is removed is required if neither mechanical or hydraulic cleaning proved successful and if the cooler is not connected to a continuously operating cleaning system.

The complete cooler with at tached header will be connected by the use of blind flanges to an external cleaning circuit or filled with detergent on the water side. Time of saturation depends on the grade of deposit. If the resultis not satisfying, cleaning should be repeated. Cleaning procedure and detergents are described under 8.2.3.1.

8.3 Cleaning of the air-side

8.3.1 General

Cleaning of the air-side should be done early enough to avoid accumulations of soot and oil on the fins, which after a period of time form a hard crust that is difficult to remove, as well as the deposition of other crack products as for instance residues that form a sulphuri cacid (compound with condensate) when left on the fins and tubes for some time.

8.3.2 Hydraulic cleaning

Hydraulic cleaning is effected when the cooler is removed.

A high pressure spray gun as described under 8.2.2 is suitable also for this requirement. We recommend a nozzle size of 3mm. If the water jet attacks the cooling tubes vertically, i .e. in parallel to the fins, a pressure of 80bar is suitable to be applied at a distance of 2m from the fin surface.

8.3.3 Chemical cleaning

We recommend chemical cleaning of the air side while the cooler is removed.

The water headers are detached from the cooler bundle. The tube bundle is then immersed into a chemical cleaning bath. The time of immersion is a function of the degree of fouling. When cleaning completed, the cooler is to be flushed by applying a poweful water jet. If the result is still not satisfying, cleaning should be repeated.

To intensify the cleaning effect of the bath and shorten the cleaning time, it is recommended to circulate the detergent. The chemical detergents can also be applied by spraying. The following detergents are recommended for air side cleaning.

The instructions and handling guidelines provided by the manufacturer of the detergent in question should always be bserved when using the chemical.

9. Tube leaks

9.1 General

Tube leaks can be caused by corrosion, erosion or improper operat ion of the cooler.

If a leakage is observed, the defective tube of tubes must be identified. If this can not be done by a visual inspection, a pressure test of the cooler of an individual pressure test of each tube has to be carried out.

9.2 Pressure test of individual tubes.

Prior to pressure testing, the connection and return headers need to be removed. In case of ample free space around the cooler it is not necessary to remove the cooler. Rubber plugs can be used for pressure test. One of the plugs must have a connection for air or water supply. The tube to be tested is plugged at both ends and tested at low pressure applied via the plug having a pressure connection.

Pressure gauges can be installed to indicate a loss of pressure. Even-if there is only a small leak in the tube a pressure loss is indicated shortly after pressure application. If the cooler is to be tested without the use of a pressure gauge it has to be dismounted to enable leakages to be found through visual control carried out from the fin side.

9.3 Pressure test of cooler

If pressure testing of the cooler is done by a hydraulic test, without removing the water headers, the fin side is searched with a flashlight for wet points indicating leaks. To avoid that damage rating being impaired by wet points on neigh boring tubes, the air side should be dried by blowing with air prior to testing.

9.4 Pressure test with air under water

If no pressure gauges are instal led pressure testing with air should be done under water.

The cooler is immersed into a water tank and tubes are tested by applying 0.5bar air pressure on the water-side without removing headers or by testing the tubes one by one as previous described. If a tube is defective bubbles will rise. However note that bubbles can from air accumlated on the cooling fins and that such bubbles do not indicate leaks.

9.5 Plugging of tubes

Once the defective tube is found it can be sealed with hard wood, rubber or brass plugs which are part of each delivery. On both sides steel plugs should not be used, due to damage of the tube sheet holes.

Plugging can be done on all tube types without exception.

In the case that several tubes are leaking it must be decided at location whether or not the cooler performance will be satisfactory after plugging.

9.6 Replacement of single tubes

If the cooler has single fin tubes, i .e. elliptical tubes with threaded on rectangular fins or round tubes with wound-on fins, it is possible to replace single tubes. If the leaking tube is found in the middle of the tube bundle, the neighboring outer tubes must be also removed and replaced to gain access to the leaking tube. After the tubes to be replaced are removed the tube sheet holes must be cleaned. The replacement tubes are provided with an extended unfinned port ion at one end. The tube is inserted into the tube hole in one tube sheet (long unfinned end first) then retracted and slid into the corresponding tube hole in the second tube sheet. Then the new tubes or then rolled into the tube sheets.

9.7 Insertion of a second core tube

Replacement of single tubes is not possible on coolers with compact fin tube system consisting of continuous fins with several inserted and expanded core tubes. To remedy tube leaks, plain tubes of smaller diameter than the defective tube can be inserted and expanded to form thermal contact with the latter and rolled into the tube sheets.

9.8 Pressure test after repair

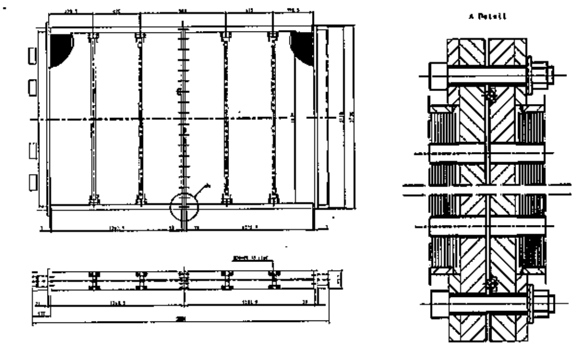
After repair the cooler must undergo a pressure test with the specified test pressure which is stated on the name plate fitted to the cooler side wall or casing. Replacement tubes, tools and other materials for leak remedy can be purchased directly from GEA Germany or GEA Industrial Heat Exchanger Systems (China) Co., Ltd or from our service centres world wide.

10. Overhaul of the Split Cooler Pre-Stage

Due to the particular design, the inspection and servicing of the cooler pre-stage is different to the conventional method used for the main stage.

10.1 Frame of pre-stage cooler

The pre-stage has been introduced for easy cleaning of the upper cooler part, which is at the most exposed to pollution. The pre-stage can be taken out and be cleaned without pulling out the whole cooler. The cooler pre-stage consist of two parts, the two tube sheets being bolted together. An O-ring seals towards the environment but not one tube to the other so that a certain (normally small) cross flow between the connected tube sheets might occur, see picture.



10.2 The special process of leak examination

10.2.1 Conventional inspection method of water leakage

The normal procedure for tube leak detection is to remove the two end covers of cooler (cooler don't need pulled out completely from the housing), close the tubes one by one at one side and apply air pressure at the other side, using professional measure equipment to check if the pressure can be hold or not. Alternatively water pressure can be applied, checking if water is leaking out or not.

10.2.2 The special process of pre-stage cooler inspection

The normal leak detection method is not suitable for split cooler pre-stages, because of the small gap at the connection tube sheets, which allows a certain cross flow. There is a very high probability that almost all tubes are falsely identified as leaking.

Therefore before checking of the cooler pre-stage the pre-stage has to be pulled out and the two parts have to be separated. They have to be checked independently according to the standard method and leaking tubes have to be plugged at each side of every pre-stage part.

10.3 The replacement of gasket and O-ring

After finishing the checking of the pre-stage parts the pre-stage cooler should be reassembled. The center O-ring needs to be replaced by a new one because of aging or shape deformation. Additionally the gaskets at the two end covers need to be changed.

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