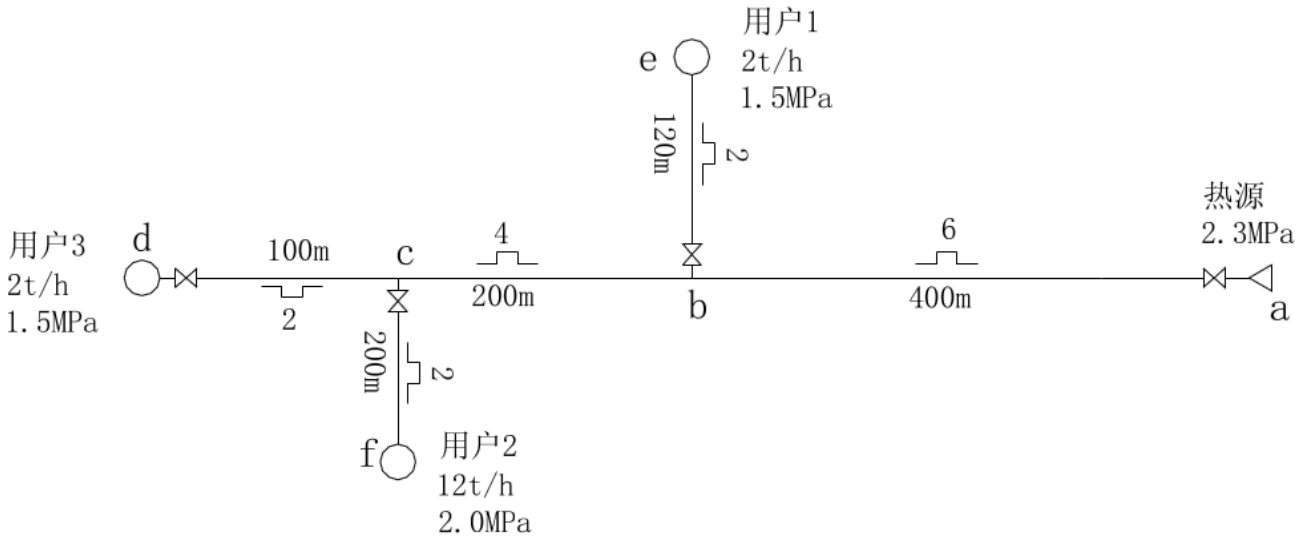
室外供汽管网的水力计算

一、绘制水力计算简图



二、确定各管段的计算流量

供汽管路中各管段的计算流量是由该管段所负担的各热用户的计算流量之和来确定的。

$$
\begin{aligned}
&\text{管段}ab \quad G_{ab}=2+12+2=16\ t/h\\
&\text{管段}bc \quad G_{bc}=12+2=14\ t/h\\
&\text{管段}be \quad G_{be}=2\ t/h\\
&\text{管段}cf \quad G_{cf}=12\ t/h\\
&\text{管段}cd \quad G_{cd}=2\ t/h
\end{aligned}
$$

三、确定供汽管路主干线及其允许平均比摩阻

主干线——热源到热用户平均比摩阻最小的一条管线

$$R_{p,j}=\frac{\Delta p}{(1+\alpha_j)\sum l}$$

Δp ——供汽管路主干线的资用压力（始端与末端的蒸汽压力差），Pa；

$\sum l$ —— 主干线长度，m；

α_j ——局部阻力当量长度占主干线长度的比例系数（指导书取值有误，短管取 0.6，长管取 0.5）

$$
\begin{aligned}
&\text{管线}abe \quad R_{p,j}=\frac{(2.3-1.5)\times10^6}{(1+0.6)(400+120)}=961.538\ Pa/m\\
&\text{管线}acf \quad R_{p,j}=\frac{(2.3-2.0)\times10^6}{(1+0.5)(400+200+200)}=250\ Pa/m\\
&\text{管线}acd \quad R_{p,j}=\frac{(2.3-1.5)\times10^6}{(1+0.5)(400+200+100)}=761.905\ Pa/m
\end{aligned}
$$

由此可知管线 acf 为主干线，其比摩阻 $R_{p,j}=250\ Pa/m$。

四、供汽管路各管段的水力计算

——从锅炉房出口开始，先计算主干线。

（一）管段 ab 计算

1、确定管段 ab 的始端和末端压力

将管段 ab 的编号、蒸汽流量和实际展开长度分别列入供汽管路水力计算表的第1～3栏。

$$p_m = p_s - \frac{p_s - p_z}{\sum l} l$$

式中：

p_m —— 管段末端蒸汽压力， MPa ；

p_s —— 管段始端蒸汽压力， MPa ；

p_z —— 主干线终端（通常是热用户）蒸汽压力， MPa ；

$\sum l$ —— 从管段始端到主干线终端的总长度， m ；

l —— 该管段的长度， m 。

管段 ab 的始端压力等于锅炉出口蒸汽压力，即 $p_s = 2.3\ MPa$ 。末端蒸汽压力 p_m ，按平均比摩阻，根据上式进行假设：

$$p_m = p_b = 2.3 - \frac{2.3 - 2.0}{400 + 200 + 200} \times 400 = 2.15\ MPa$$

查饱和水和饱和水蒸汽表，得：

$$\begin{aligned} p_s = 2.3\ MPa \text{ 时} \qquad & \rho_s = 12.019\ kg/m^3 \\ p_m = 2.15\ MPa \text{ 时} \qquad & \rho_m = 11.263\ kg/m^3 \end{aligned}$$

2、求出该管段蒸汽的平均密度

$$\rho_{p,j} = \frac{\rho_s + \rho_m}{2}$$

式中：

ρ_s —— 计算管段始端压力 p_s 下的蒸汽密度， kg/m^3 ；

ρ_m —— 计算管段末端压力 p_m 下的蒸汽密度， kg/m^3 。

$$\rho_{p,j} = \frac{12.019 + 11.263}{2} = 11.641\ kg/m^3$$

将 p_s 、 ρ_s 、 p_m 、 ρ_m 和 $\rho_{p,j}$ 分别列入供汽管路水力计算表的第4～8栏。

将 $R_{p,j}$ 值换算为蒸汽管路水力计算表 $\rho_0 = 1\ kg/m^3$ 条件下的允许平均比摩阻值 $R_{0,p,j}$ ，即：

$$R_{0,p,j} = \rho_{p,j} \cdot R_{p,j} = 11.641 \times 250 = 2910.25\ Pa/m$$

将 $R_{0,p,j}$ 值列入表的第9栏。

3、由平均密度、 R 、 G 求出 d

$$R = 6.88 \times 10^{-3} K^{0.25} \frac{G^2}{\rho d^{5.25}} = f(G, d, \rho)$$

得到

$$
\begin{aligned}
d &= 0.378\frac{K^{0.0476}\cdot G^{0.381}}{(\rho R)^{0.19}} \\
&= 0.378\frac{0.0002^{0.0476}\cdot 16^{0.381}}{(11.641\times 250)^{0.19}} \\
&= 0.159\ m
\end{aligned}
$$

4、由 d 确定相近的公称直径

从教材附录13-1供汽管路水力计算表中选择最相近的蒸汽管道的直径 $d=150mm$，根据 $G'=16\ t/h$ 条件，得到流速为 $v_0=252\ m/s$，$R_0=4439.4\ Pa/m$

将 R_0、v_0 和管径 DN 值分别列入水力计算表的第10～12栏。

5、由公称直径确定真实的 R

$$
\begin{aligned}
R_{sh} &= \frac{1}{\rho_{p,j}}R_0 = \frac{1}{11.641}\times 4439.4 = 381.359\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}}v_0 = \frac{1}{11.641}\times 252 = 21.648\ m/s
\end{aligned}
$$

将 R_{sh} 和 v_{sh} 分别列入水力计算表的第13、14栏。

6、由 R 计算末端压力 p'_m

根据选用的管径 $\mathrm{DN}=150\mathrm{mm}$，按教材附录9-2，求出管段 ab 的当量长度 l_d 值及其折算长度 l_{zh} 值，并计算管段 ab 在假设平均密度条件下的实际压力降。

管段 ab 的局部阻力组成有：1个截止阀，6 个方形补偿器（锻压弯头）。查教材附录9-2得：

$$
l_{d,0} = 24.6 + 6\times 15.4 = 117\ m
$$

由于蒸汽管道的实际当量绝对粗糙度 K_{sh} 一般为 $0.2\ mm$，与教材附录9-2中采用的 $K_0=0.5mm$ 不同，因此，应乘上修正系数 $\beta=1.26$，对 $l_{d,0}$ 进行修正：

$$
l_{d,sh} = 1.26\times 117 = 147.42\ m
$$

管段 ab 的折算长度：

$$
l_{zh} = l + l_{d,sh} = 400 + 147.42 = 547.42\ m
$$

管段 ab 在假设平均密度条件下的实际压力降：

$$
\Delta p_{sh} = R_{sh}l_{zh} = 381.359\times 547.42 = 208763.544\ Pa = 0.209\ MPa
$$

管段 ab 在假设平均密度条件下的实际末端压力：

$$
p'_m = p_s - \Delta p_{sh} = 2.3 - 0.209 = 2.091\ MPa
$$

将 p'_m 值列入表的第18栏。

7、由末端压力计算平均密度

根据管段 ab 在假设平均密度条件下的实际末端压力 p'_m，查出相应的末端蒸汽密度 $\rho'_m=10.988\ kg/m^3$。再根据公式求出管段 1 中蒸汽的实际平均密度 $\rho'_{p,j}$：

$$
\rho'_{p,j} = \frac{\rho_s + \rho'_m}{2} = \frac{12.019 + 10.988}{2} = 11.504\ kg/m^3
$$

8、验算平均密度

$$\frac{\rho_{p,j}-\rho'_{p,j}}{\rho'_{p,j}}=\frac{11.641-11.504}{11.504}=1.19\%$$

由于相对误差偏大，因此需重新计算。

9、按新密度再计算

$$\begin{aligned}
p_m&=2.091\ MPa\\
\rho_m&=10.988\ kg/m^3\\
\rho_{p,j}&=\frac{\rho_s+\rho_m}{2}=\frac{12.019+10.988}{2}=11.504\ kg/m^3\\
R_{0,p,j}&=\rho_{p,j}\cdot R_{p,j}=11.504\times 250=2876\ Pa/m\\
d&=0.378\frac{K^{0.0476}\cdot G^{0.381}}{(\rho R)^{0.19}}=0.378\frac{0.0002^{0.0476}\cdot 16^{0.381}}{(11.504\times 250)^{0.19}}=0.160\ m\\
R_{sh}&=\frac{1}{\rho_{p,j}}R_0=\frac{1}{11.504}\times 4439.4=385.901\ Pa/m\\
v_{sh}&=\frac{1}{\rho_{p,j}}v_0=\frac{1}{11.504}\times 252=21.905\ m/s\\
\Delta p_{sh}&=R_{sh}l_{zh}=385.901\times 547.42=211249.925\ Pa=0.211\ MPa\\
p'_m&=p_s-\Delta p_{sh}=2.3-0.211=2.089\ MPa\\
\rho'_m&=10.978\ kg/m^3\\
\rho'_{p,j}&=\frac{\rho_s+\rho'_m}{2}=\frac{12.019+10.978}{2}=11.499\ kg/m^3\\
\frac{\rho_{p,j}-\rho'_{p,j}}{\rho'_{p,j}}&=\frac{11.504-11.499}{11.499}=0.043\%
\end{aligned}$$

误差很小可忽略，结束管段ab的计算。

（二）管段 bc 计算

$$
\begin{aligned}
p_s &= 2.089\ MPa \\
\rho_s &= 10.978\ kg/m^3 \\
p_m &= p_c = 2.089 - \frac{2.089 - 2.0}{200 + 200} \times 200 = 2.045\ MPa \\
\rho_m &= 10.762\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{10.870 + 10.762}{2} = 10.870\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 10.870 \times 250 = 2717.5\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 14^{0.381}}{(10.924 \times 250)^{0.19}} = 0.153\ m \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{10.870} \times 4439.4 = 408.408\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{10.870} \times 252 = 23.183\ m/s \\
l_{d,0} &= 4 \times 15.4 = 61.6\ m \\
l_{d,sh} &= 1.26 \times 61.6 = 77.616\ m \\
l_{zh} &= l + l_{d,sh} = 200 + 77.616 = 277.616\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 408.408 \times 277.616 = 113380.595\ Pa = 0.113\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.089 - 0.113 = 1.976\ MPa \\
\rho'_m &= 10.422 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{10.978 + 10.422}{2} = 10.700\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{10.870 - 10.700}{10.700} = 1.59\%
\end{aligned}
$$

误差较大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s &= 2.089\ MPa \\
\rho_s &= 10.978\ kg/m^3 \\
p_m &= 1.976\ MPa \\
\rho_m &= 10.422\ kg/m^3 \\
\rho_{p,j} &= 10.700\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 10.700 \times 250 = 2675\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 14^{0.381}}{(10.700 \times 250)^{0.19}} = 0.154\ m \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{10.700} \times 4439.4 = 414.897\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{10.700} \times 252 = 23.551\ m/s \\
l_{zh} &= 277.616\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 414.897 \times 277.616 = 115182.046\ Pa = 0.115\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.089 - 0.115 = 1.977\ MPa
\end{aligned}
$$

已小于终端所需压力，需重新计算。

（三）管段 ab 第三次计算

管段 ab 选择 $DN=200$，根据 $G'=16\ t/h$ 条件，得到流速为 $v_0=132\ m/s$，$R_0=819.3\ Pa/m$

$$
\begin{aligned}
R_{sh}&=\frac{1}{\rho_{p,j}}R_0=\frac{1}{11.641}\times 819.3=70.381\ Pa/m\\
v_{sh}&=\frac{1}{\rho_{p,j}}v_0=\frac{1}{11.641}\times 132=11.339\ m/s\\
l_{zh}&=547.42\ m\\
\Delta p_{sh}&=R_{sh}l_{zh}=70.381\times 547.42=38527.967\ Pa=0.039\ MPa\\
p'_m&=p_s-\Delta p_{sh}=2.3-0.039=2.261\ MPa\\
\rho'_m&=11.827\ kg/m^3\\
\rho'_{p,j}&=\frac{\rho_s+\rho'_m}{2}=\frac{12.019+11.827}{2}=11.923\ kg/m^3\\
\frac{\rho_{p,j}-\rho'_{p,j}}{\rho'_{p,j}}&=\frac{11.641-11.923}{11.923}=-2.365\%
\end{aligned}
$$

误差较大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s&=2.3\ MPa\\
\rho_s&=12.019\ kg/m^3\\
p_m&=2.261\ MPa\\
\rho_m&=11.827\ kg/m^3\\
\rho_{p,j}&=\frac{\rho_s+\rho_m}{2}=\frac{12.019+11.827}{2}=11.923\ kg/m^3\\
R_{0,p,j}&=\rho_{p,j}\cdot R_{p,j}=11.923\times 250=2980.75\ Pa/m\\
d&=0.378\frac{K^{0.0476}\cdot G^{0.381}}{(\rho R)^{0.19}}=0.378\times\frac{0.0002^{0.0476}\cdot 16^{0.381}}{(11.923\times 250)^{0.19}}=0.159\ m\\
R_{sh}&=\frac{1}{\rho_{p,j}}R_0=\frac{1}{11.923}\times 819.3=68.716\ Pa/m\\
v_{sh}&=\frac{1}{\rho_{p,j}}v_0=\frac{1}{11.923}\times 132=11.071\ m/s\\
l_{d,0}&=39.5+6\times 23.4+12.6=192.5\ m\\
l_{d,sh}&=1.26\times 192.5=242.55\ m\\
l_{zh}&=l+l_{d,sh}=400+242.55=642.55\ m\\
\Delta p_{sh}&=R_{sh}l_{zh}=68.716\times 642.55=44153.466\ Pa=0.044\ MPa\\
p'_m&=p_s-\Delta p_{sh}=2.3-0.044=2.256\ MPa\\
\rho'_m&=11.802\ kg/m^3\\
\rho'_{p,j}&=\frac{\rho_s+\rho'_m}{2}=\frac{12.019+11.802}{2}=11.911\ kg/m^3\\
\frac{\rho_{p,j}-\rho'_{p,j}}{\rho'_{p,j}}&=\frac{11.923-11.911}{11.911}=0.101\%
\end{aligned}
$$

误差很小可忽略，结束管段ab的计算。

（四）管段 bc 第三次计算

$$
\begin{aligned}
p_s &= 2.256\ MPa \\
\rho_s &= 11.802\ kg/m^3 \\
p_m &= p_c = 2.256 - \frac{2.256 - 2.0}{200 + 200} \times 200 = 2.128\ MPa \\
\rho_m &= 11.170\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{11.802 + 11.170}{2} = 11.486\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 11.486 \times 250 = 2871.5\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 14^{0.381}}{(11.486 \times 250)^{0.19}} = 0.152\ m \\
&\text{取 DN} = 150 \\
R_0 &= 3400.6\ Pa/m \\
v_0 &= 220\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{11.486} \times 3400.6 = 296.065\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{11.486} \times 220 = 19.154\ m/s \\
l_{d,0} &= 4 \times 15.4 + 8.4 = 70\ m \\
l_{d,sh} &= 1.26 \times 70 = 88.2\ m \\
l_{zh} &= l + l_{d,sh} = 200 + 88.2 = 288.2\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 296.065 \times 288.2 = 85325.933\ Pa = 0.085\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.256 - 0.085 = 2.171\ MPa \\
\rho'_m &= 11.383\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.802 + 11.383}{2} = 11.593\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{11.486 - 11.593}{11.593} = -0.923\%
\end{aligned}
$$

误差较大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s &= 2.256\ MPa \\
\rho_s &= 11.802\ kg/m^3 \\
p_m &= 2.171\ MPa \\
\rho_m &= 11.383\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{11.802 + 11.383}{2} = 11.593\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 11.593 \times 250 = 2898.25\ Pa/m \\
R_0 &= 3400.6\ Pa/m \\
v_0 &= 220\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{11.593} \times 3400.6 = 293.332\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{11.593} \times 220 = 18.977\ m/s \\
l_{zh} &= l + l_{d,sh} = 200 + 88.2 = 288.2\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 293.332 \times 288.2 = 84538.282\ Pa = 0.085\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.256 - 0.085 = 2.171\ MPa \\
\rho'_m &= 11.383\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.802 + 11.383}{2} = 11.593\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{11.593 - 11.593}{11.593} \approx 0\%
\end{aligned}
$$

误差可忽略，结束管段bc的计算。

（五）管段 cf 计算

$$
\begin{aligned}
p_s &= 2.171\ MPa \\
\rho_s &= 11.383\ kg/m^3 \\
p_m &= p_f = 2.0\ MPa \\
\rho_m &= 10.540\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{11.383 + 10.540}{2} = 10.962\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 10.962 \times 250 = 2740.5\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 12^{0.381}}{(10.962 \times 250)^{0.19}} = 0.144\ m
\end{aligned}
$$

取 $\mathrm{DN} = 150$

$$
\begin{aligned}
R_0 &= 2499\ Pa/m \\
v_0 &= 189\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{10.962} \times 2499 = 227.969\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{10.962} \times 189 = 17.241\ m/s \\
l_{d,0} &= 24.6 + 2 \times 15.4 + 8.4 = 63.8\ m \\
l_{d,sh} &= 1.26 \times 63.8 = 80.388\ m \\
l_{zh} &= l + l_{d,sh} = 200 + 80.388 = 280.388\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 227.969 \times 280.388 = 63919.772\ Pa = 0.064\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.171 - 0.064 = 2.107\ MPa \\
\rho'_m &= 11.067\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.383 + 11.067}{2} = 11.225\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{10.962 - 11.225}{11.225} = -2.343\%
\end{aligned}
$$

误差较大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s &= 2.171\ MPa \\
\rho_s &= 11.383\ kg/m^3 \\
p_m &= 2.107\ MPa \\
\rho_m &= 11.067\ kg/m^3 \\
\rho_{p,j} &= 11.225\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 11.225 \times 250 = 2806.25\ Pa/m \\
R_0 &= 2499\ Pa/m \\
v_0 &= 189\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{11.225} \times 2499 = 222.628\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{11.225} \times 189 = 16.837\ m/s \\
l_{zh} &= l + l_{d,sh} = 200 + 80.388 = 280.388\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 222.628 \times 280.388 = 62422.220\ Pa = 0.062\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.171 - 0.062 = 2.109\ MPa \\
\rho'_m &= 11.077\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.383 + 11.077}{2} = 11.230\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{11.225 - 11.23}{11.23} = -0.045\%
\end{aligned}
$$

误差可忽略，结束管段cf的计算，盈余压力采用压力调节阀降压。

（六）管段 be 计算

$$
\begin{aligned}
p_s &= p_b = 2.256\ MPa \\
\rho_s &= 11.802\ kg/m^3 \\
p_m &= p_e = 1.5\ MPa \\
\rho_m &= 8.088\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{11.802 + 8.088}{2} = 9.945\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 9.945 \times 961.538 = 9562.495\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 2^{0.381}}{(9.945 \times 961.538)^{0.19}} = 0.057\ m \\
&\text{取 DN} = 65 \\
R_0 &= 2332.4\ Pa/m \\
v_0 &= 111\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{9.945} \times 2332.4 = 234.530\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{9.945} \times 111 = 11.161\ m/s \\
l_{d,0} &= 9.3 + 2 \times 6.4 = 22.1\ m \\
l_{d,sh} &= 1.26 \times 22.1 = 27.846\ m \\
l_{zh} &= l + l_{d,sh} = 120 + 27.846 = 147.846\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 234.530 \times 147.846 = 34674.322\ Pa = 0.034\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.256 - 0.034 = 2.222\ MPa \\
\rho'_m &= 11.634\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.802 + 11.634}{2} = 11.718\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{9.945 - 11.718}{11.718} = -15.131\%
\end{aligned}
$$

误差过大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s &= 2.256\ MPa \\
\rho_s &= 11.802\ kg/m^3 \\
p_m &= 2.222\ MPa \\
\rho_m &= 11.634\ kg/m^3 \\
\rho_{p,j} &= 11.718\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 11.718 \times 961.538 = 11267.302\ Pa/m \\
R_0 &= 2332.4\ Pa/m \\
v_0 &= 111\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{11.718} \times 2332.4 = 199.044\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{11.718} \times 111 = 9.473\ m/s \\
l_{zh} &= l + l_{d,sh} = 147.846\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 199.044 \times 147.846 = 29427.859\ Pa = 0.029\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.256 - 0.029 = 2.227\ MPa \\
\rho'_m &= 11.659\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.802 + 11.659}{2} = 11.731\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{11.718 - 11.731}{11.731} = -0.111\%
\end{aligned}
$$

误差可忽略，结束管段be的计算，盈余压力采用压力调节阀降压。

（七）管段 cd 计算

$$
\begin{aligned}
p_s &= 2.171\ MPa \\
\rho_s &= 11.383\ kg/m^3 \\
p_m &= p_d = 1.5\ MPa \\
\rho_m &= 8.088\ kg/m^3 \\
\rho_{p,j} &= \frac{\rho_s + \rho_m}{2} = \frac{11.383 + 8.088}{2} = 9.736\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 9.736 \times 761.905 = 7417.526\ Pa/m \\
d &= 0.378 \frac{K^{0.0476} \cdot G^{0.381}}{(\rho R)^{0.19}} = 0.378 \times \frac{0.0002^{0.0476} \cdot 2^{0.381}}{(9.736 \times 761.905)^{0.19}} = 0.060\ m \\
&\text{取 DN} = 65 \\
R_0 &= 2332.4\ Pa/m \\
v_0 &= 111\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{9.736} \times 2332.4 = 239.565\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{9.736} \times 111 = 11.401\ m/s \\
l_{d,0} &= 9.3 + 2 \times 6.4 = 22.1\ m \\
l_{d,sh} &= 1.26 \times 22.1 = 27.846\ m \\
l_{zh} &= l + l_{d,sh} = 100 + 27.846 = 127.846\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 239.565 \times 127.846 = 30627.427\ Pa = 0.031\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.171 - 0.031 = 2.140\ MPa \\
\rho'_m &= 11.230\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.383 + 11.230}{2} = 11.307\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{9.736 - 11.307}{11.307} = -13.894\%
\end{aligned}
$$

误差较大，需重新计算。

按新密度再计算

$$
\begin{aligned}
p_s &= 2.171\ MPa \\
\rho_s &= 11.383\ kg/m^3 \\
p_m &= 2.140\ MPa \\
\rho_m &= 11.230\ kg/m^3 \\
\rho_{p,j} &= 11.307\ kg/m^3 \\
R_{0,p,j} &= \rho_{p,j} \cdot R_{p,j} = 11.307 \times 239.565 = 2708.761\ Pa/m \\
R_0 &= 2332.4\ Pa/m \\
v_0 &= 111\ m/s \\
R_{sh} &= \frac{1}{\rho_{p,j}} R_0 = \frac{1}{11.307} \times 2332.4 = 206.279\ Pa/m \\
v_{sh} &= \frac{1}{\rho_{p,j}} v_0 = \frac{1}{11.307} \times 111 = 9.817\ m/s \\
l_{zh} &= l + l_{d,sh} = 147.846\ m \\
\Delta p_{sh} &= R_{sh} l_{zh} = 206.279 \times 147.846 = 30497.525\ Pa = 0.030\ MPa \\
p'_m &= p_s - \Delta p_{sh} = 2.256 - 0.030 = 2.226\ MPa \\
\rho'_m &= 11.654\ kg/m^3 \\
\rho'_{p,j} &= \frac{\rho_s + \rho'_m}{2} = \frac{11.383 + 11.654}{2} = 11.519\ kg/m^3 \\
\frac{\rho_{p,j} - \rho'_{p,j}}{\rho'_{p,j}} &= \frac{11.307 - 11.519}{11.519} = -0.184\%
\end{aligned}
$$

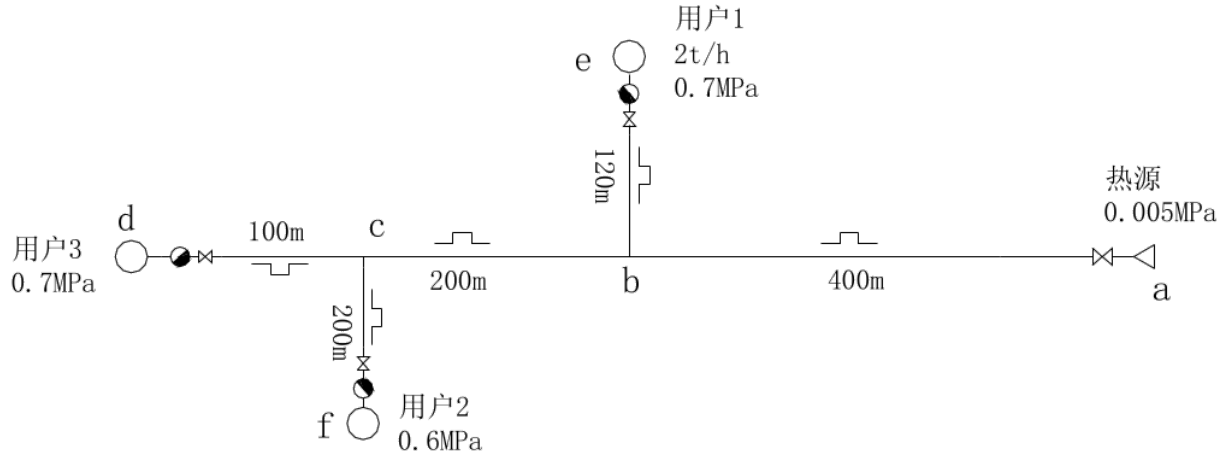
误差可忽略，结束管段cd的计算，盈余压力采用压力调节阀降压。

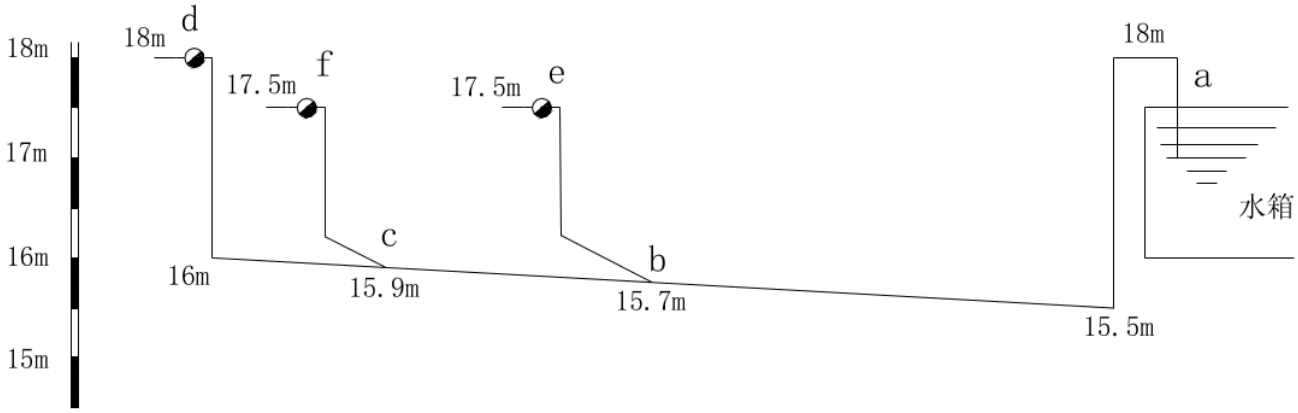
供汽管路水力计算表（分段平均密度法）

管段编号	蒸汽流量 G' t/h	实际长度 l m	假设始端压力 p_s MPa	假设始端密度 ρ_s kg/m^3	假设末端压力 p_m MPa	假设末端密度 ρ_m kg/m^3	假设平均密度 $\rho_{p,j}$ kg/m^3	$\rho_1=1kg/m^3$ 条件下允许比摩阻 $R_{0,j}$ Pa/m	$\rho_1=1kg/m^3$ 条件下查表比摩阻 R_0 Pa/m	$\rho_1=1kg/m^3$ 条件下查表流速 v_0 m/s	公称直径 DN mm	平均密度 $\rho_{p,j}$ 条件下实际比摩阻 $R_{p,j}$ Pa/m	平均密度 $\rho_{p,j}$ 条件下实际流速 v_{sh} m/s	当量长度 l_d m	折合长度 l_{zh} m	实际压力降 Δp_{sh} MPa	实际末端压力 p'_m MPa	实际末端密度 ρ'_m kg/m^3	实际平均密度 $\rho'_{p,j}$ kg/m^3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
主干线																			
ab	16	400	2.3	12.019	2.15	11.263	11.641	2910.25	4439.4	252	150	381.359	21.648	147.42	547.42	0.209	2.091	10.988	11.504
		400	2.3	12.019	2.091	10.988	11.504	2876	4439.4	252	150	385.901	21.905	147.42	547.42	0.211	2.089	10.978	11.499
		400	2.3	12.019	2.15	11.263	11.641	2910.25	819.3	132	200	70.381	11.339	147.42	547.42	0.039	2.261	11.827	11.923
		400	2.3	12.019	2.261	11.827	11.923	2980.75	819.3	132	200	68.716	11.071	242.55	642.55	0.044	2.256	11.802	11.911
bc	14	200	2.256	11.802	2.128	11.170	11.486	2871.5	3400.6	220	150	296.065	19.154	88.2	288.2	0.085	2.171	11.383	11.593
		200	2.256	11.802	2.171	11.383	11.593	2898.25	3400.6	220	150	293.332	18.977	88.2	288.2	0.085	2.171	11.383	11.593
cf	12	200	2.171	11.383	2.0	10.540	10.962	2740.5	2499	189	150	227.969	17.241	80.388	280.388	0.064	2.107	11.067	11.225
		200	2.171	11.383	2.107	11.067	11.225	2806.25	2499	189	150	222.628	16.837	80.388	280.388	0.062	2.109	11.077	11.230
分支线																			
bc	2	120	2.256	11.802	1.5	8.088	9.945	9562.495	2332.4	111	65	234.530	11.161	27.846	147.846	0.034	2.222	11.634	11.718
		120	2.256	11.802	2.222	11.634	11.718	11267.304	2332.4	111	65	199.044	9.473	27.846	147.846	0.029	2.227	11.659	11.731
cd	2	100	2.171	11.383	1.5	8.088	9.736	7417.526	2332.4	111	65	239.565	11.401	27.846	127.846	0.031	2.140	11.230	11.307
		100	2.171	11.383	2.140	11.230	11.307	2708.761	2332.4	111	65	206.279	9.817	27.846	127.846	0.030	2.226	11.654	11.519

室外余压凝结水回收管网的水力计算

一、绘制水力计算简图





二、主干线计算

由 $R_{p,j}=\dfrac{\Delta p}{(1+\alpha_j)\sum l}$，得

$$
\begin{aligned}
&\text{管线}eba \qquad R_{p,j}=\frac{(0.7-0.005)\times 10^6}{(1+0.6)(400+120)}=835.337\ Pa/m\\
&\text{管线}fca \qquad R_{p,j}=\frac{(0.6-0.005)\times 10^6}{(1+0.5)(400+200+200)}=495.833\ Pa/m\\
&\text{管线}dca \qquad R_{p,j}=\frac{(0.7-0.005)\times 10^6}{(1+0.5)(400+200+100)}=661.905\ Pa/m
\end{aligned}
$$

由此可知管线 fca 为主干线，其比摩阻 $R_{p,j}=464.844\ Pa/m$。

1、计算主干线管路的二次蒸汽量（百分数）

各车间疏水器前的凝水表压力为：

$$
\begin{aligned}
p_{1,e}&=0.95p_e=0.95\times 0.7=0.665\ MPa\\
p_{1,f}&=0.95p_f=0.95\times 0.6=0.57\ MPa\\
p_{1,d}&=0.95p_d=0.95\times 0.7=0.665\ MPa
\end{aligned}
$$

查水蒸汽表得各用户疏水器前 p_1 压力下饱和凝水的焓为：

$$h_{1,e}=713.10\ kJ/kg$$
$$h_{1,f}=689.94\ kJ/kg$$
$$h_{1,d}=713.10\ kJ/kg$$

已知 $p_a=0.005\ MPa$，查表得：$h_a=422.38\ kJ/kg$；$\gamma_a=2254.8\ kJ/kg$。

根据

$$x_2=\frac{h_1-h_3}{\gamma_3}$$

式中：

h_1 ——疏水器前 p_1 压力下饱和凝水的焓，kJ/kg；

h_3 ——凝水管路末端 p_3 压力下饱和凝水的焓，kJ/kg；

γ_3 ——凝水管路末端 p_3 压力下蒸汽的汽化潜热，kJ/kg。

$$x_{2,e}=\frac{713.10-422.38}{2254.8}=0.129$$
$$x_{2,f}=\frac{689.94-422.38}{2254.8}=0.119$$
$$x_{2,d}=\frac{713.10-422.38}{2254.8}=0.129$$

设疏水器的漏汽率均为 $x_1=0.03$。因此，根据

$$x=\frac{\sum[G_i(x_{1,i}+x_{2,i})]}{\sum G_i}$$

主干线末端的二次蒸汽量（百分数）为：

$$x=0.03+\frac{2\times0.129+8\times0.119+2\times0.129}{2+8+2}=0.1523$$

2、计算主干线 fca 的全线汽水混合物的大致平均密度

为使计算简单，采用全程平均密度法，并取主干线末端汽水混合物密度作为主干线各管段的平均密度。

查水蒸汽表，凝水箱压力 p_a 下的饱和蒸汽比容为：$v_q=1.64\ m^3/kg$，v_s 近似采用 $0.001\ m^3/kg$，根据

$$\rho_x=\frac{1}{v_x}=\frac{1}{x(v_q-v_s)+v_s}$$

式中：

ρ_x ——汽水混合物的密度，kg/m^3；

v_x ——汽水混合物的比容，m^3/kg；

v_s ——凝水比容，m^3/kg，可近似取 $v_s=0.001\ m^3/kg$；

v_q ——在凝水管段末端压力 p_a 下的饱和蒸汽比容，m^3/kg；

x ——管段末端汽水混合物中所含蒸汽的质量百分数。

可得：

$$\rho_x=\frac{1}{0.1523\times(1.64-0.001)+0.001}=3.990\ kg/m^3$$

3、计算资用压力及允许平均比摩阻

$$\Delta p = (p_2 - p_3) - H\rho g$$

取 $p_{2,f} = 0.5 p_{1,f} = 0.5 \times 0.57 = 0.285\ MPa$，得:

$$\begin{aligned}\Delta p &= (p_{2,f} - p_3) - H\rho g \\ &= (0.285 - 0.005) \times 10^6 - (18 - 18) \times 1000 \times 9.8 \\ &= 280000\ Pa\end{aligned}$$

主干线的 α_j 值取等于 0.5，则主干线的平均比摩阻 $R_{p,j}$ 为

$$R_{p,j} = \frac{\Delta p}{(1+\alpha_j)\sum l} = \frac{280000}{(1+0.5) \times (400+200+200)} = 233.333\ Pa/m$$

4、确定管子的理论管径

按管壁粗糙度 $K = 1.0\ mm$，密度 $\rho_x = 3.990\ kg/m^3$，平均比摩阻 $R_{p,j} = 233.333\ Pa/m$ 以及主干线各管段的计算流量 G'，计算各管段的管子理论内径 d_l：

$$\begin{aligned}d_l &= 0.378 \frac{K^{0.0476} \cdot G'^{0.381}}{(\rho_x R_{p,j})^{0.19}} \\ &= 0.378 \frac{0.0001^{0.0476} \cdot G'^{0.381}}{(5.437 \times 464.844)^{0.19}} \\ &= 0.067 \times G'^{0.381}\ m\end{aligned}$$

因此

$$\begin{aligned}d_{ab,l} &= 0.067 \times G'^{0.381} = 0.067 \times 12^{0.381} = 0.171\ m \\ d_{bc,l} &= 0.067 \times G'^{0.381} = 0.067 \times 10^{0.381} = 0.160\ m \\ d_{cf,l} &= 0.067 \times G'^{0.381} = 0.067 \times 8^{0.381} = 0.147\ m\end{aligned}$$

5、确定管子的实际管径

由于管径规格与计算的理论管径不可能刚好一致，因此，要在管径规格中选用接近的管径。实际选用的管子尺寸为:

管段ab : $(D_w \times \delta)_{sh} = 219 \times 6$	实际内径$d_{ab,sh} = 0.207\ m$
管段bc : $(D_w \times \delta)_{sh} = 219 \times 6$	实际内径$d_{ab,sh} = 0.207\ m$
管段cf : $(D_w \times \delta)_{sh} = 159 \times 4.5$	实际内径$d_{ab,sh} = 0.150\ m$

6、计算管子的实际比摩阻和流速

当计算流量和汽水混合物密度不变，而管径由计算内径 d_l 改变为实际管径 d_{sh} 时，平均比摩阻也将从 $R_{p,j}$ 变为 R_{sh}

$$R_{sh} = \left(\frac{d_l}{d_{sh}}\right)^{5.25} R_{p,j}$$

$$\text{管段}ab: \quad R_{sh} = \left(\frac{0.171}{0.207}\right)^{5.25} \times 233.333 = 85.578\ Pa/m$$

$$\text{管段}bc: \quad R_{sh} = \left(\frac{0.160}{0.207}\right)^{5.25} \times 233.333 = 60.362\ Pa/m$$

$$\text{管段}cf: \quad R_{sh} = \left(\frac{0.147}{0.150}\right)^{5.25} \times 233.333 = 209.852\ Pa/m$$

各管段的实际流速:

$$v_{sh}=\frac{10G'}{9\pi d_{sh}^2\rho_x}=\frac{10G'}{9\pi d_{sh}^2\times 5.437}=\frac{0.065G'}{d_{sh}^2}$$

管段ab：$v_{sh}=\dfrac{0.065\times 12}{0.207^2}=18.203\ m/s$

管段bc：$v_{sh}=\dfrac{0.065\times 10}{0.207^2}=15.170\ m/s$

管段cf：$v_{sh}=\dfrac{0.065\times 8}{0.150^2}=23.111\ m/s$

7、计算各管段的压力损失及管段始端（节点 b、c 和用户 f 疏水器后）的实际压力

管段 ab 的压力损失为

$$\begin{aligned}\Delta p_{ab}&=R_{sh,ab}l_{ab}(1+\alpha_j)\\&=85.578\times 400\times(1+0.5)=51346.717\ Pa\end{aligned}$$

管段 ab 始端（节点 b）的实际压力为

$$\begin{aligned}p_b&=p_a+\Delta p_{ab}+(Z_{m,ab}-Z_{s,ab})\rho g\\&=0.005\times 10^6+51346.717+(18-15.7)\times 1000\times 9.81\\&=78909.717\ Pa\end{aligned}$$

式中:

$Z_{m,ab}$ ——管段 ab 末端标高，m；

$Z_{s,fe}$ ——管段 fe 始端标高，m。

对于管段 bc 和 cf，采用同样计算方法，可得:

$$\begin{aligned}\Delta p_{bc}&=R_{sh,bc}l_{bc}(1+\alpha_j)\\&=60.362\times 200\times(1+0.5)=18108.6\ Pa\\p_c&=p_b+\Delta p_{bc}+(Z_{m,bc}-Z_{s,bc})\rho g\\&=78909.717+18108.6+(15.7-15.9)\times 1000\times 9.81\\&=95056.317\ Pa\end{aligned}$$

$$\begin{aligned}\Delta p_{cf}&=R_{sh,cf}l_{cf}(1+\alpha_j)\\&=209.852\times 200\times(1+0.5)=62955.6\ Pa\\p_f&=p_c+\Delta p_{cf}+(Z_{m,cf}-Z_{s,cf})\rho g\\&=95056.317+62955.6+(15.9-17.5)\times 1000\times 9.81\\&=142315.917\ Pa\end{aligned}$$

计算结果显示，疏水器后的实际压力 p_f 小于设计值 $p_{2,f}=0.285\ MPa$，设计偏于安全。

主干线水力计算过程和结果的有关数据见室外余压回水管网水力计算表。

三、分支线计算

1、管段 be

取疏水器后凝水压力为 $p_{2,e}=0.5p_{1,e}=0.5\times 0.95\times 0.7=0.3325\ MPa$。管段末端压力为 $p_b=78909.717\ Pa$，因此管段 be 的资用压力为:

$$\begin{aligned}\Delta p&=(p_{2,e}-p_b)-H\rho g\\&=(332500-78909.717)-(15.7-17.5)\times 1000\times 9.8\\&=271230.283\ Pa\end{aligned}$$

管段比摩阻为:

$$R_{p,j}=\frac{\Delta p}{(1+\alpha_j)\sum l}=\frac{271230.283}{(1+0.6)\times 120}=1412.658\ Pa/m$$

按上述步骤和方法，可求得

$$\begin{aligned}
x&=x_1+x_2=0.003+0.129=0.132\\
\rho_x&=\frac{1}{x(v_q-v_s)+v_s}=\frac{1}{0.132\times(0.764-0.001)+0.001}=9.831\ kg/m^3\\
d_l&=0.378\frac{K^{0.0476}\cdot G'^{0.381}}{(\rho_x R_{p,j})^{0.19}}\\
&=0.378\frac{0.0001^{0.0476}\cdot 2^{0.381}}{(9.831\times 1412.658)^{0.19}}\\
&=0.0518\ m\\
(D_w\times\delta)_{sh}&=76\times 3.5\ mm\\
\text{实际内径}d_{cd,sh}&=0.069\ m\\
\text{实际比摩阻}R_{sh}&=\left(\frac{d_l}{d_{sh}}\right)^{5.25}R_{p,j}=\left(\frac{0.0534}{0.069}\right)^{5.25}\times 1412.658=367.850\ Pa/m\\
\text{管段压力损失}\Delta p_{be}&=R_{sh,be}l_{be}(1+\alpha_j)=367.850\times 120\times(1+0.6)=70627.2\ Pa\\
\text{疏水器后的实际压力}p_e&=p_b+\Delta p_{be}+(Z_{m,be}-Z_{s,be})\rho g\\
&=78909.717+70627.2+(15.7-17.5)\times 1000\times 9.81\\
&=131878.917\ Pa\\
\text{凝水流速}v_{sh}&=\frac{0.065G'}{d_{sh}^2}=\frac{0.065\times 2}{0.069^2}=27.305\ m/s
\end{aligned}$$

管段 be 水力计算过程和结果的有关数据见室外余压回水管网水力计算表。

2、管段 cd

取疏水器后凝水压力为 $p_{2,d}=0.5p_{1,d}=0.5\times 0.95\times 0.7=0.3325\ MPa$。管段末端压力为 $p_c=95056.317\ Pa$，因此管段 cd 的资用压力为:

$$\begin{aligned}
\Delta p&=(p_{2,d}-p_c)-H\rho g\\
&=(332500-95056.317)-(15.9-18)\times 1000\times 9.8\\
&=258023.683\ Pa
\end{aligned}$$

管段比摩阻为:

$$R_{p,j}=\frac{\Delta p}{(1+\alpha_j)\sum l}=\frac{258023.683}{(1+0.5)\times 100}=1720.158\ Pa/m$$

按上述步骤和方法，可求得

$$
\begin{aligned}
x &= x_1 + x_2 = 0.003 + 0.119 = 0.122 \\
\rho_x &= \frac{1}{x(v_q - v_s) + v_s} = \frac{1}{0.122 \times (0.674 - 0.001) + 0.001} = 12.033\ kg/m^3 \\
d_l &= 0.378 \frac{K^{0.0476} \cdot G'^{0.381}}{(\rho_x R_{p,j})^{0.19}} \\
&= 0.378 \frac{0.0001^{0.0476} \cdot 2^{0.381}}{(12.033 \times 1720.158)^{0.19}} \\
&= 0.0481\ m \\
(D_w \times \delta)_{sh} &= 57 \times 3.5\ mm \\
\text{实际内径} d_{cd,sh} &= 0.050\ m \\
\text{实际比摩阻} R_{sh} &= \left(\frac{d_l}{d_{sh}}\right)^{5.25} R_{p,j} = \left(\frac{0.0481}{0.050}\right)^{5.25} \times 1720.158 = 1396.981\ Pa/m \\
\text{管段压力损失} \Delta p_{cd} &= R_{sh,cd} l_{cd} (1 + \alpha_j) = 1396.981 \times 100 \times (1 + 0.5) = 209547.15\ Pa \\
\text{疏水器后的实际压力} p_d &= p_c + \Delta p_{cd} + (Z_{m,cd} - Z_{s,cd}) \rho g \\
&= 95056.317 + 209547.15 + (15.9 - 18) \times 1000 \times 9.81 \\
&= 284002.467\ Pa \\
\text{凝水流速} v_{sh} &= \frac{0.065 G'}{d_{sh}^2} = \frac{0.065 \times 2}{0.050^2} = 52\ m/s
\end{aligned}
$$

管段 cd 水力计算过程和结果的有关数据见室外余压回水管网水力计算表。

3、疏水器余压（背压）的运行调节

上述水力计算结果显示，各疏水器的设计余压（背压）分别为：

$$
\begin{aligned}
p_{2,e} &= 131878.917\ Pa \\
p_{2,f} &= 142315.917\ Pa \\
p_{2,d} &= 284002.467\ Pa
\end{aligned}
$$

设计时，应在各用户疏水器后的凝水出口处设置调节阀门和压力表（设在调节阀门后面）。凝水管路初次运行时，应用调节阀门逐个调整各疏水器的实际背压，使之接近设计背压；正常运行时，如发现某用户凝水回水不畅，则应适当开大疏水器后的阀门，同时应观察其它用户的回水情况，以免影响其它用户的回水。

室外余压回水管网水力计算表

管段	凝水计算流量 G' t/h	管段实际长度 l m	局部阻力折合长度比值 α_j	管段平均密度 ρ_x kg/m^3	允许比摩阻 $R_{p,j}$ Pa/m	理论管子直径 d_l mm	选用管径 $D_w \times \delta$ mm	实际内径 d_{sh} mm	实际比摩阻 R_{sh} Pa/m	实际流速 v m/s	实际压力损失 Δp Pa	管段初始端压力 p_s Pa
1	2	3	4	5	6	7	8	9	10	11	12	13
主干线		800	0.5	3.990	233.333							
ab	12	400	0.5	3.990	233.333	0.171	219×6	207	85.578	18.203	51346.7	78909.717
bc	10	200	0.5	3.990	233.333	0.160	219×6	207	60.362	15.170	18106.6	95056.317
cf	8	200	0.5	3.990	233.333	0.147	159×4.5	150	209.852	23.111	62955.6	142315.917
分支线												
be	2	120	0.6	9.831	1412.658	0.0518	76×3.5	69	367.850	27.305	70627.2	131878.917
cd	2	100	0.5	12.033	1720.158	0.0481	57×3.5	50	1396.981	52	209547.15	284002.467