RESEARCH ARTICLE OPEN ACCESS
Website: http://ijte.americanjournal.us/index.php/ijte

International Journal of Technology & Energy
Volume 1, Number 3, 2025 | ISSN: 3066-6635

Cooling Load Analysis on the KAIS Semeru Train PPI Madiun

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Abstract

Trains are a means of transportation with large capacity and low transportation costs. The cooling system on trains has an excessive load received by passengers, causing discomfort for passengers. The purpose of this study is to determine the capacity of the air freshener machine that is appropriate to the needs of the train. The method used is an analytical method, where data collection is used as a research guideline in solving the problem of cooling load on trains in this case related to the temperature in an area to be calculated. The air conditioning system plays an important role in supporting the achievement of thermal comfort levels. Thermal comfort in trains can be achieved if passengers get an ideal temperature supply, humidity level, and air movement from their environment. Based on calculations that have been done, KAIS Semeru has a cooling load of 94.3 kW.

Keywords: cooling, KAIS, semeru, PPI madiun

INTRODUCTION

Air conditioning is currently widely used in various sectors, including industry, housing, shops, offices, hotels, and vehicles. It can be used in cars, buses, trains, ships, and airplanes. This is compounded by the increasing human need for comfort at work, including the need for appropriate temperature, humidity, and airflow. It is expected that the tasks required of them will be carried out correctly and precisely. This also applies to operator personnel, for example, as train drivers. This is all done through the development of air conditioning systems that continue to develop. Air conditioning is needed to provide a comfortable, fresh, and clean air environment. Therefore, air processing is necessary to regulate temperature, humidity, and cleanliness, and distribute them simultaneously to meet the desired comfort. Therefore, research is important to analyze the cooling load on the Semeru Train. This is to determine the capacity of the air freshener machine that is appropriate to the train's needs. For passengers and restrooms, it is necessary to calculate the heat load that must be removed and design the room system to be conditioned. This cooling load calculation includes sensible and latent loads, including loads from outside air passing through walls, roofs, floors, passenger loads, loads from electrical equipment, ventilation and infiltration. In addition to calculating the cooling load, it is also necessary to plan air distribution so that all spaces can be conditioned according to their needs. Research on air conditioning on the Semeru Train obtained the OTTV (Overall Thermal Transfer Value) of the latest design by changing the window area (train windows) and wall area so that the WWR value in the new train design is smaller, namely WWR of 0.253 from the previous 0.549 [1]. The purpose of the study is to provide comfortable, fresh, and clean air environmental conditions on the Semeru Train. Based on the description above, it is important to analyze the cooling load on the Semeru Train,

A refrigerator is a device used to absorb heat from a cold reservoir (cooled room) with the help of a compressor to then be released into a hotter reservoir. It regulates temperature, humidity, cleanliness and distribution simultaneously to achieve comfortable conditions. Air conditioning systems are generally divided into two main groups, namely air conditioning for comfort and air conditioning for industry[2]. Basically, the principles of cooling and air conditioning are guided by the conditions below.

	Suhu Kemudi Depan	Suhu Kemudi Belakang	Suhu Ruang penumpang	Suhu Ruang Mesin	Suhu Ruang Toilet
Min	17,1%C	17,1%C	17,1%C	17,1%C	17,1%C
Max	33,5%C	33,5%C	33,5%C	33,5%C	33,5%C
Suhu yang diukur	32,1%C	28,7%C	29,8%C	26,6%C	28,7%C

In hot weather, simply cooling the air may not necessarily cool the body if the humidity is still high. At low humidity, an air temperature of 30-32°C is generally sufficient to keep our bodies cool and comfortable. However, at high humidity, an air temperature of 24-30°C, the body still feels uncool. The difference in indoor and outdoor temperatures should not exceed 15°F

(8.4-11°C). The effects of temperature changes on human health have been studied. A cool and comfortable room temperature is 75-80°F (24-27.7°C). Packaged air fresheners consist of a fan, air coil, air filter, and a storage tank located at the top of the house. This type of air freshener consists of the air freshener and refrigerator located in one house. Air induced through the inlet will reach the desired temperature and humidity. The air is then forced into the plenum chamber at the top of the fan and then into the room. Packaged air fresheners, which sometimes serve multiple rooms, introduce air into the room through a pipe from the plenum chamber. The air coil used is usually a direct expansion type (Dx coil), where the liquid refrigerant from the condenser is evaporated, resulting in the air flowing through the coil becoming cool and dry.

By applying this phenomenon to a refrigeration machine, we obtain a refrigeration machine that can reuse refrigerant repeatedly in a closed cycle. A refrigeration machine consists of four main components:

1. Evaporator
2. Compressor
3. Condenser
4. Expansion valve

The series of these four components is like this:

1. Evaporator

This is where the refrigerant evaporates from a liquid to a gas (vapor). This process occurs isobaric and results in an increase in enthalpy.

2. Compressor

Refrigerant vapor is sucked in by the compressor and then compressed until it reaches a pressure level where it can easily condense in the condenser. This process occurs isentropic with an increase in enthalpy.

3. Condenser

Refrigerant condensation occurs in the condenser, where the refrigerant vapor changes to liquid in an isobaric process with a decrease in enthalpy.

4. Expansion valve

The refrigerant undergoes a process of pressure and temperature reduction, occurring in the isenthalpic state.

Tabel 2. Komponen pendingin kereta api

Nama Komponen	Spesifikasi	
Air Conditioning	*Sistem*	*Cooling*
	Model	T. 6014.V
	Cooling Capacity	18.6 kW
Compressor	*Compressor Type*	*Full Hermatic*
	Quantity	2 Pcs
	Power Supply	380 V
	Power Input	2 x 3,1 kW
Condesor Oil	*Tube*	Material *Copper grooved copper*
	Daya Masuk	1 kW
	Type	SKF 6306
	Cooling Capacity	15000 Kcal/hr
Refrigerant	*Type Control Charge*	R22
		Thermostatic Expantion Valve 5000

Filter Dryer.

Compressor.

METHOD

The method used is an analytical method, where data collection is used as a research guideline in solving problems. The research location is at the KAIS Semeru workshop of the Indonesian Railway Polytechnic, Madiu. Identification of the variables sought in the study is in the form of air temperature in Bandung and KAIS Semeru Engineering data for both external and internal loads.

Data collection and processing techniques:

1. Primary data, data obtained directly from KAIS Semeru

The research began by developing ideas or concepts in the KAIS Semeru case as follows:

a. Discovery and titling of research.
b. Search for references related to the research title.

c. Look for relevant theories and equations used in problem solving.
d. Searching for objects and requesting approval for research implementation.
e. Obtain troubleshooting estimates on cooling loads.
f. Data collection based on predetermined time.
g. Data is processed and analyzed.
h. Obtaining a discussion in the form of data calculated using relevant equations.

RESULTS AND DISCUSSION

1. Comparison of OTTV (OVERALL THERMAL TRANSFER VALUE) values of KAIS SEMERU.

OTTV (Overall Thermal Transfer Value) is a figure or total thermal transfer value that is determined as a design criterion for a conditioned building envelope. The calculation of OTTV (Overall Thermal Transfer Value) based on SNI 03-6389-2000 [4], stipulates that the OTTV (Overall Thermal Transfer Value) value does not exceed 45 Watt/m2. In this study, the OTTV (Overall Thermal Transfer Value) value and cooling load of KAIS Semeru will be calculated.

1.1 Determining the WWR (Window to Wall ratio) Value

is the ratio of the window area to the area of all the outer walls in the orientation

which is determined

It is known that KAIS Semeru:

1.1 Determining the WWR (Window to Wall Ratio) Value

a. Train wall

Train length	=20 m
Train width/height	=1,067 m
Total area of the train walls	=18.2 mx1.9m
	=34,581m2

b. Train window

Large wall window area	=128cmx48cm
	=10,150cm2
	=1,015m2
(multiplied by 4 there are 4 wall windows)	=4,116m^2
Small wall window area	=103cmx80cmx43cm
	=354,320cm3
	=35,432m2
(multiplied by 4 there are 4 wall windows)	= 141,728m2 Total area of wall
windows (large+small)	= 145,884 m^2Door window area
	=81cmx43.5cm

Total windowsdoor =3523.5cm^2

=0.35m2

Total wall windows + total door windows =(145.884+0.35)m2

=146,234m2

c. Train door

Door area =0.73mx1.85cm

=1.3505m2

d. Calculating the WWR (Window to Wall Ratio) value.

$$WWR = \frac{Window}{Anding}$$

Awall = Total wall area – Total window area wall–total door area (wall + window)

Awall = 34,581m2+145,884m2+(1.3505+0.35)m2

Awalls = 34,581m2+145,884m2+1,7005m2

Awall= 182,165m2

Awindow = Total area of window wall + Total area of window door = 145.884 m2 + 0.35 m2

Awindow = 146,234m2

So the WWR value $= \frac{Window}{Anding}$

$= \frac{146,234}{182,165}$

= 0.80

1.2 Determining the OTTV (Overall Thermal Transfer Value) value

a. α(Solar radiation absorbance)

$$atotal = \frac{a\ aluminum+defect}{2}$$

$$\alpha\ total = \frac{0.12+0.25}{2}$$

αtotal=0.185

b. Uwall (wall transmittance) = 0.412Watt/m2K

c. TDEK (equivalent temperature difference), based on SNI03-6389-2000 Weight/unit area (kg/m2) less than 125 = 15K

d. SC (Shading Coefficient) or shading coefficient of the SC fenestration system = 0.57

e. SF (Solar Radiation Factor) = 147

f. Table

1. Solar Radiation Factor (SF,W/m2)

No	Orientation	Information
1	U	130
2	TL	113
3	T	112
4	TG	97
5	S	97
6	BD	176
7	B	243
8	BL	211

Calculation of the OTTV (Overall Thermal Transfer Value) value based on equation (2.1) as follows:

$OTTV=\alpha.[(U_{w}.(1\text{-}WWR)].TDEK+(SC.WWR.SF)+(Uf.WWRx\Delta T)$

=0.185[(0.412x(1–0.108)]x15+(0.57x0.108x147)+(2.89x0.108x5)

=(0.185x0.37x15)+(0.57x0.108x147)+(2.89x0.108x5)

=1.026+9.04+1.56

=11,626 Watts/m2

2. Cooling Load Calculation Using the CLTD (Cooling Load Temperature Difference) Method

2.1 Internal Load

a. Passenger Load

QPassengers = (Qsensible+Qlatent)xnumber of passengers

=(70W+45W)x14 people

=1,610 W

b. Electronic Equipment Load

Table 2.Electronic Equipment for Semeru PPIMadiun Inspection Train

Burden	Voltage	Total Load	Watt Power
Electric socket	220	6 units	14
air conditioning	380	1 unit	7150
Telephone	220	2 units	40
Television	220	1 unit	100
TL Lamp	220	9 units	20
LampuSembol	220	8 units	120

Q=Electronic equipment x installed power

Q=84W+7150W+80W+100W+1800W+960WWQ=10.174W

c. Lighting Load

Qlight =8625Wx3.4Wx1.25W
=36.656W

The total internal load is the sum of the passenger load, electronic equipment load, and lighting load. So the total internal load is as follows: Total internal load

=passenger load + electronic equipment load + lighting load

=1,610 W+9240 W+36,565 W
=47.415W

2.2 External Load

a. LoadConductionThroughWind

owKnown:

U =1.71W/m2.°C(ASHRAEHANDBOOK1997,Table5Chapter29)A

=146,234m^2

Twindow =22°C (Ministerial Regulation 7 of 2022 concerning the implementation of high-speed trains)

Qwindow =U xAxCLTD

=1.71W/m2.°Cx146.234m2x(27-22)°C
=1,250.301W

a. Conduction LoadThrough the RoofKnown:

U =0.26W/m2.°C(ASHRAEHANDBOOK1997,Table3Chapter36)A

=8.92mx2.05m=18.286m^2

Troof =22°C (Ministerial Regulation 7 of 2022 concerning the implementation of high-speed trains)Toutside =27°C (average temperature of Madiun, BMKG)

Qroof =U xAxCLTD

=0.26W/m2.°Cx18.286m2x(27-22)°C

=23.7718W

b. LoadConductionThroughWallKnown:

U =0.26W/m2.°C(ASHRAEHANDBOOK1997,Table3Chapter36)A =165.8705m^2

Twall =22°C (Ministerial Regulation 7 of 2022 concerning the implementation of high-speed trains)Toutside =27°C (average temperature of Madiun, BMKG)

Qwall =U xAxCLTD

=0.26W/m2.°Cx165.8705m2x(27-22)°C

=215.6317W

Calculating the Total Cooling Load and Conduction Load of the Roof

=23.7718W

Qwall =215.6317W

Qwindow =1250.301W

So, the total conduction load is as follows:

Qconduction =Qroof+Qwall+Qwindow

=1,489.705W

c. Known

FloorPartition Load:

U =4.60W/m2.°C(ASHRAEHANDBOOK1997,Table4Chapter24)A

=8.92mx2.05m=18.286m^2

Troom =22°C (PM7 of 2022 concerning the implementation of high-speed trains)

Qfloor =U xAxCLTD

=4.60W/m2.°Cx18.286m2x(27-22)°C

=420.578W

b. Solar Radiation Load on Glass is known:

Awindow =146,234m2

SC =0.57(ASHRAE1997*Chapter*29)

SCL =545(ASHRAE*HANDBOOK*1997, Table 36 Chapter 28)

Qglass radiation=Ajendelax(SC)x(SCL)

=146.234x0.57x545

=45,427.59W

So, the total solar radiation through the glass is 45427.59W

2.3 Ventilation and Infiltration

a. KnowingQsensible ventilation

Tenvironment=27°C (average temperature of Madiun, BMKG)

Troom = 22°C (PM7 of 2022 regarding the implementation of speed trainstall)

Ventilation rate,Q =1,800m^{3}h

=0.5 liters/s

Qsensible =1.23x0.5x(27-22)°C

=3.075 W

b. KnowingQlatent ventilation

Wenvironment = 0.0178/kg (at temperature 27 °C and RH 79 %)Wroom= 0.0099/kg (at temperature 22 °C and RH 60%)Ventilation rate, Q = =1,800m3h

=0.5 liters/s

Qlatent =3.010x0.5x(0.0178-0.0099)

=11.8895W

c. Knowing

QtotalVentilationQTOTAL=Qsensible+ Qlatent

=3.075W+11.8895W

=14.9645W

Total cooling load inspection train yellow PPI madiun table3.Total cooling load value

Internal Load	Mark
Passenger	1,610W
Lighting	36.656WElectronic
Equipment	10.174W Total Internal
Load	48,440W

External Load	Mark
Conduction Load	1,489,705W
Partition Load	420,578WGlassRadiationLoad
	45,427.59WVentilation Glass
	11.8895 WTotal External Load
	45,860.06W

TotalCoolingLoad =load*internal*+external load

=48,440W+45,860.06W

=94,300.06W

CONCLUSION

There are several factors that influence the cooling load on a train, including the conduction, convection, and radiation processes on the walls, roof, floor, and windows of the train. In addition, passengers, electronic equipment, ventilation, and infiltration are factors that influence the cooling load.Based on the calculations that have been carried out, KAIS Semeru has a cooling load of 94.3 kW.

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