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Final Design Report of the Design of A Climate Controlled Sleeping Chamber for Infants and Toddlers

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FINAL DESIGN REPORT
OF THE DESIGN OF
A CLIMATE CONTROLLED SLEEPING CHAMBER
FOR INFANTS AND TODDLERS

By Jennifer Stenger Stevens

In partial completion of the requirements for
graduation from the
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ABSTRACT

This is the design project final report for the design of a climate controlled sleeping chamber for infants and toddlers. Another name for such a chamber is "air crib". The concept of an air crib originated in the 1960's by psychologist/author B.F. Skinner.

An air crib is an alternative sleeping medium to the conventional crib. It is a chamber that is temperature and humidity controlled to provide an optimum sleeping environment for young children. The design of such a chamber requires engineering analysis of four subsystems- ventillation, heating, humidification, and control system. The result is an alternative to the conventional crib at a cost that is not prohibitive.

Climate Controlled Sleeping Chamber

Introduction

A climate controlled sleeping chamber, or air crib, for infants and toddlers is an alternative sleeping medium to the conventional crib. It is a chamber that is ventillated with air that is temperature and humidity controlled to provide an optimum sleeping environment for young children, ages Ø to 2 years. Its purpose is to enhance the psychological and physiological development of young children. Because it is easier to heat a small chamber than larger living quarters, the air crib also has economic advantages.

The design of climate controlled sleeping chamber must meet some minimum requirements. The system must provide an environment in which a young child between the ages of Ø and 2 years may sleep. This environment must be temperature and humidity controlled to a maximum of 95 degrees Fahrenheight and 5Ø% relative humidity, respectively. It must fit into a 6 foot by 8 foot room and must be large enough to contain the child comfortably. It must also maintain a comfortable environment without undo draft or noise. The unit must be able to regulate the temperature and humidity over an extended period of time to within +5% with little or no maintenance. It should be run by

household power and all water supplies may be self-contained. The system cannot have a retail value much greater than that of a standard crib. Finally, the system must meet all safety standards set for infant sleeping furniture and residential safety codes in heating, ventillation, electrical wiring, and child safety.

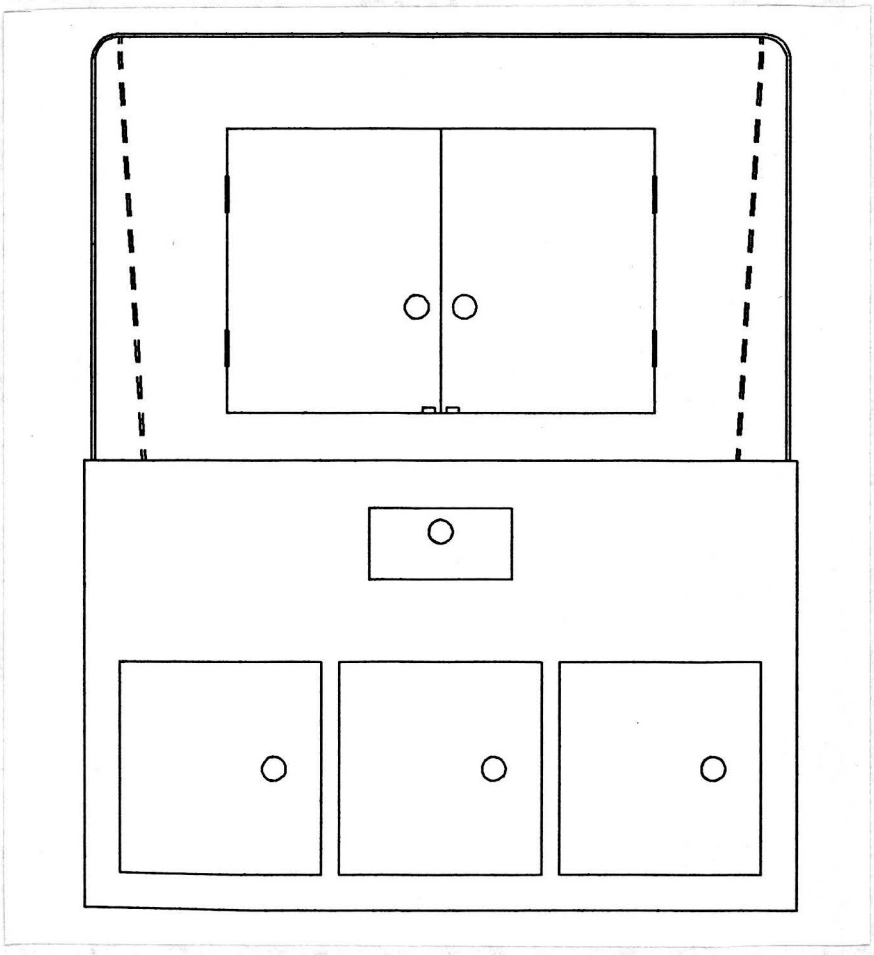


Figure 1: A Climate Controlled Sleeping Chamber

Summary

The system I designed has a hardwood base that houses four subsystems and the chamber shell. The chamber is enclosed by 1/4" acrylic panels reinforced with 1" x 1/2" acrylic supports. The enclosure has openings to allow for air movement, recirculation, and access to the chamber.

The four subsystems housed in the base are :

1) ventillation system,

2) heating system,

3) humidification system, and

4) control system.

The design of these four systems is the major emphasis of this design project. Other considerations in this design are unit aesthetics and cost analysis.

Systems Design

Ventillation System

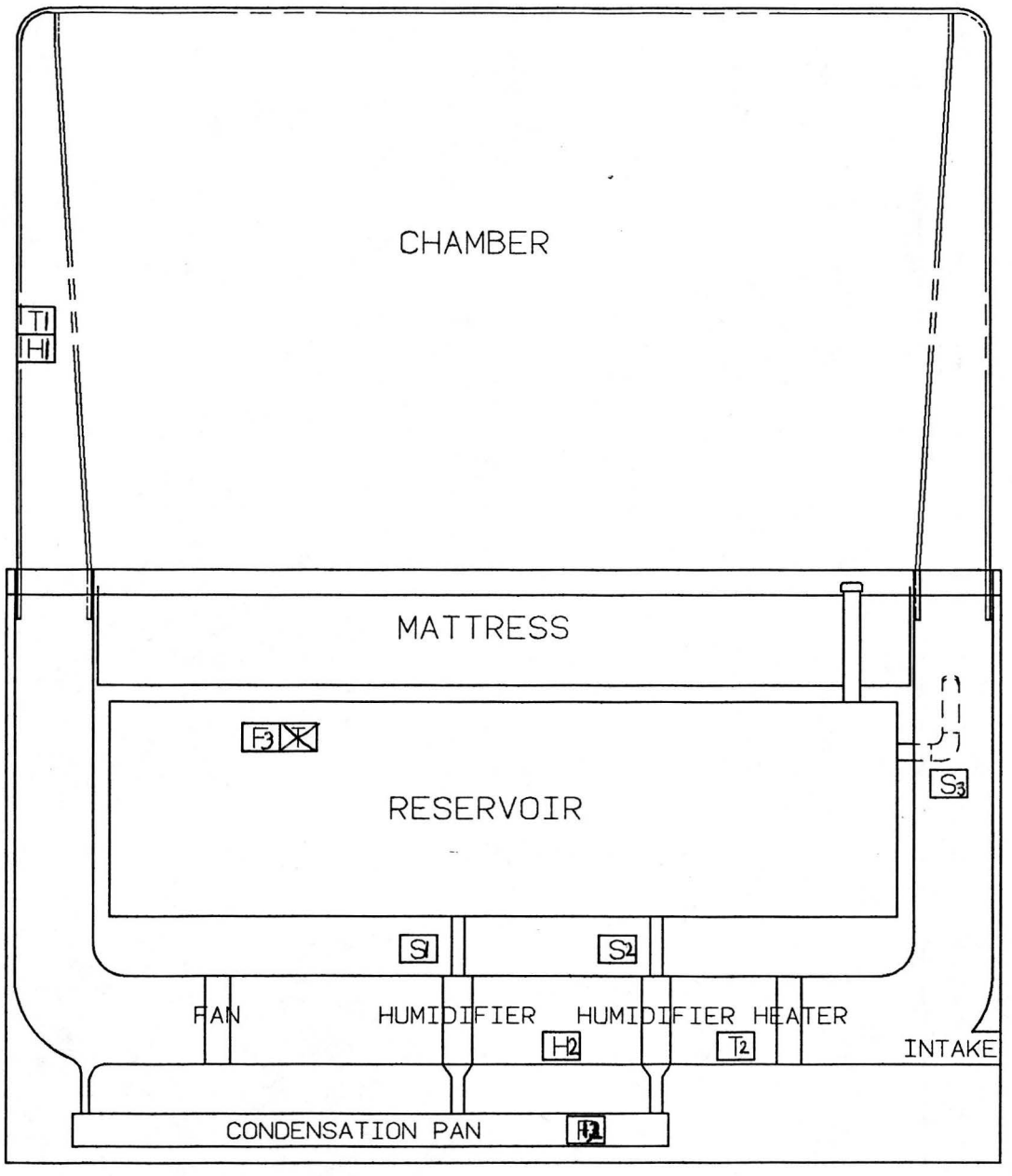
The ventillation system consists of a 26 gage sheet metal duct housed in the base of the unit and acrylic panels with openings that serve as louvers attached to the acrylic bubble that serves as the chamber. The volume of the chamber is approximately 45 cubic feet, and requires two air changes per

minute for sufficient ventillation.[2] This yeilds a flow rate of 90 cubic feet per minute (cfm). Calculating the pressure head using equivalent resistances of ducts yeild a required static pressure head of .156" water. Pamotor Fan model #4600X[3] moves 90 cfm at .16" static pressure, which is satisfactory for this purpose.

In order to maintain proper air speed across the heating and humidifying units, a face velocity of 450 feet per minute (fpm) to 750 fpm is required.[4] At 90 cfm, the equivalent diameter of a round duct to satisfy this requirement is between 4.944 inches and 9.383 inches. To optimize the face velocity requirements for heating coils and filters, I chose to use a face velocity of 450 fpm At 90 cfm, this yeilds a duct area of 28.8 square inches. A square duct of 5 3/8" by 5 3/8" satisfies this requirement. although I realize that good duct design would require I chose duct dimensions of a more rectangular nature,[5] this design is satisfactory for this project. In the short distance of the duct, a square duct of odd dimensions is suitable. The square duct expands on each end of the unit to the area required to enter the chamber. An opening in the exterior of the bubble permits some of the heated and humidified air to be vented into the room. This method recirculates approximately 65% of the conditioned air. An intake duct introduces fresh air.

LEGEND

H	HUMIDISTAT
T	THERMOSTAT
F	FLOAT VALVE
S	SOLENOID VALVE



FRONT VIEW

FIGURE 2 : VENTILLATION SYSTEM

Heating System

The heating element is a single unit inside the ventillation duct that uses Nichrome wire wound on 5 ceramic cores 1/8" thick each with an effective length of 4 inches. The original design was to use ribbon elements, but the resistance per foot, 179 Ω/ft, was much too high, so coils are recommended. Each element has 32 coils per inch. This reduced the resistance requirement to 12.90 Ω/ft. Nichrome V gage# 33 wire has a resistance of 12.90Ω/ft. This is a suitable resistance for this application. The elements draw 1/2 amp, which corresponds to a temperature of 200 degrees Fahrenheit. A heat transfer anaylsis proves this to be an acceptable value. Also, the low amperage rating limits the possibility of dangerous electrical shock.

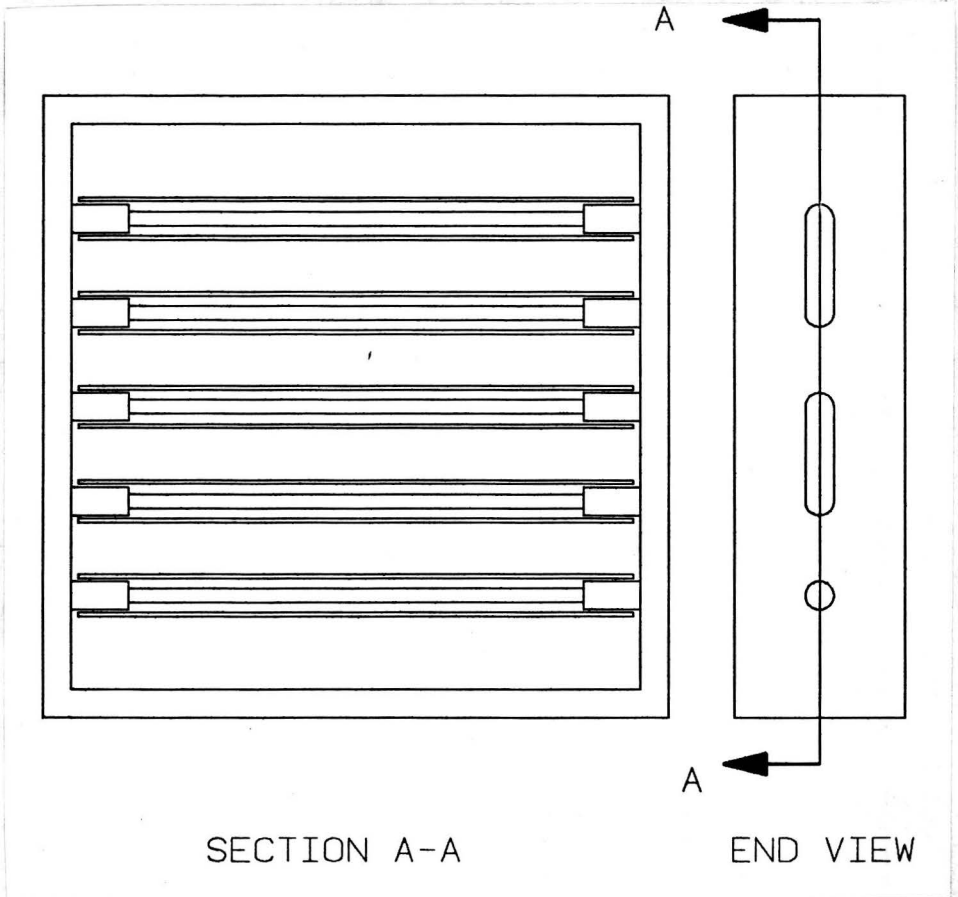


FIGURE 3: HEATER

Humidification System

The humidification system uses two humidifiers to bring the air to the required 50% relative humidity (rh). Originally, I had chosen to use a heated pan humidifier for the pre-humidifier, but efficiency and safety considerations prompted me to use filter humidifiers in both locations.[7] Both filter humidifiers use aluminum mesh screens as a medium for evaporation. Aluminum mesh screen is more easily cleaned, generates less odor, and does not encourage bacterial growth. It can also withstand a greater face velocity. Water from a reservoir is fed to the screens by 1/4" copper tubing. The flow rate is controlled by solenoid valves which, in turn, are controlled by humidistats- one in the duct, set at 20% relative humidity and one in the chamber set at 50% relative humidity. A condensation pan below the duct captures any unevaporated moisture from the humidifiers and any condensation from the duct walls. This is a safety measure since there should be no condensation from the walls.

Control Circuit

The control circuit, as shown in figure 4, uses 120 VAC household power. A 5 amp fuse protects the circuit from overload. A separate safety circuit sounds a horn and flashes a

light should the household power go off while the unit is in operation. Magnetic switch, K, controls the normally closed (NC) switch, Ko, in the safety circuit. The fan is in parallel with the magnetic and the other elements of the circuit. Shown also are the thermostats and humidistats which control the electric heater and solenoid valves, respectively. Also, there is a float valve in the reservoir connected to the solenoid valve which controls the flow of water into the reservoir. A float valve in the condensation pan insures against unusually high flows of water into the pan by closing the solenoid valves that control the flow into the humidifiers. The instrument panel with the control knobs of these systems is shown in figure 5. Particular emphasis on unit aesthetics was placed on the design of the control panel as it is the major interface between the user and the system.

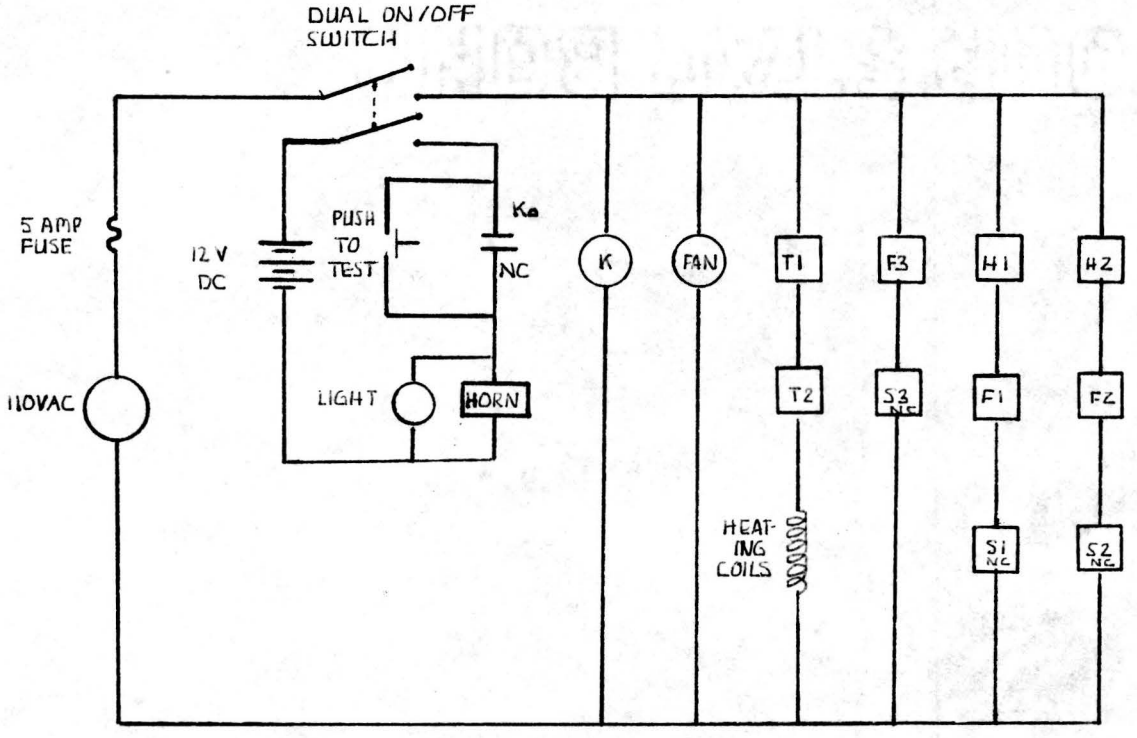


FIGURE 4: ELECTRICAL CIRCUIT

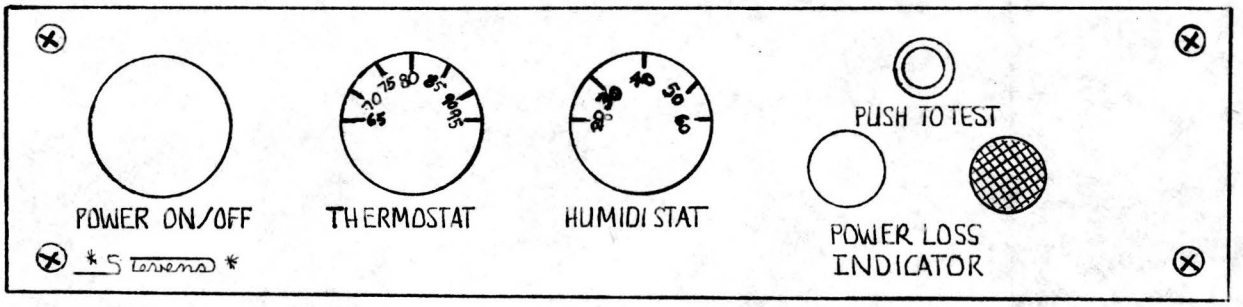


FIGURE 5: CONTROL PANEL

Cost Analysis

In my cost analysis, the calculated final cost is $21,526, $20,000 of which is engineering labor cost. At first glance, this cost is prohibitive. However, it is not truly representative of the cost to mass produce a number of units, over which the engineering cost can be spread. The materials cost only $460 (this is a liberal estimate). Labor costs for one unit excluding the engineering cost amounted to $1,125. With the benefits of mass production, the entire unit could cost between $500 and $700. This indicates that, given a public interest in this type of device and a wide range of styles, manufacturing this product is feasible and could be profitable. It is not a highly sophisticated system so that repair and maintenance would not be a major concern. Finally, the unit is collapsable enough it can be stored in half the space it occupies while it is in use. The hardwood base and rounded corners of the acrylic bubble add to its attractiveness.

Conclusions

The design of a climate controlled sleeping chamber is an integrative project requiring the design and analysis of four systems- the ventillation system, the heating system, the humidification system and the control system. The ventillation system uses a sheet metal duct which houses the heater, pre-humidifier, humidifier, and the fan. It vents into the chamber providing partially recirculated, conditioned air. The heating system is comprised of a single heater with five heating elements of Nichrome V wire wound in coils on 1/8" ceramic cores. The two humidifiers are filter humidifiers with aluminum mesh matting. The control circuit controls all the systems and has the added feature of a safety circuit that warns parents if the power to the unit is somehow interrupted. The control panel was design to appeal to the senses and be easily understood by an operator. Through out the design process, safety requirements were considered although specific codes and standards are not mentioned in the body of this report.

The cost of the system could be between $500 and $700, a reasonable price for this unit. The hardwood base would also appeal to the public, making this project feasible for manufacturing.

END NOTES

1 ASHRAE Handbook; Equipment, 1979, pg. 5.1

2 Industrial Ventillation; 17th Edition, 1982, pg. 2-5

3 Pamoter Catalog, pg. 8

4 Heating, Ventillating, and Air Conditioning, 1984, pg. 701

5 Ibid, pg. 699

6 Pelican Wire Company Stock List, 1985, pg. 2

7 National Electric Code, 1983

BIBLIOGRAPHY

ASHRAE Handbook; Equipment 1979

ASHRAE Handbook; Fundamentals 1981

Fundamental Principles and Applications of Fluid Mechanics, Flammer, Jeppson, Keedy, USU Press, Logan, Utah 1982

Fundamentals of Classical Thermodynamics, SI Version 2e, Revised Printing, Van Wylen and Sonntag, John Wiley and Sons, New York 1978

Fundamentals of Heat Transfer, Incropera and Dewitt, John Wiley and Sons, New York 1982

Fundamentals of Physics, 2nd Edition, Extended Version, Halliday and Resnick, John Wiley and Sons, New York 1982

Handbook of Air Conditioning System Design, Carrier Air Conditioning Company, McGraw-Hill, New York 1965

Handbook of Chemistry and Physics, 64th Edition, 1983-84, Weast, CRC Press, Inc., Florida 1984

Heating, Ventillating, and Air Conditioning, Clifford, Reston Publishing Company, Virginia 1984

Industrial Ventillation, 17th Edition: Manual of Recommended Practice, Committee on Industrial Ventillation, Edward Brothers, Ann Arbor, Michigan 1982

Mechanics of Materials, 3rd Edition, Higdon, Ohlsen, Stiles, Weese, Riley, John Wiley and Sons, New York 1977

National Electric Code, 1978 Edition, National Fire Protection Association, Boston, Massechusetts 1978

PAMOTOR Catalog-Fans, Blowers, Accessories, Catalog #13-149-0675, Pamotor Company, Burlingame, California 1984

Piping Handbook, 5th Edition, Crocker and King, McGraw-Hill, New York 1968

Standard Handbook for Mechanical Engineers, 7th Edition, Baumeister and Marks, McGraw-Hill, New York 1975

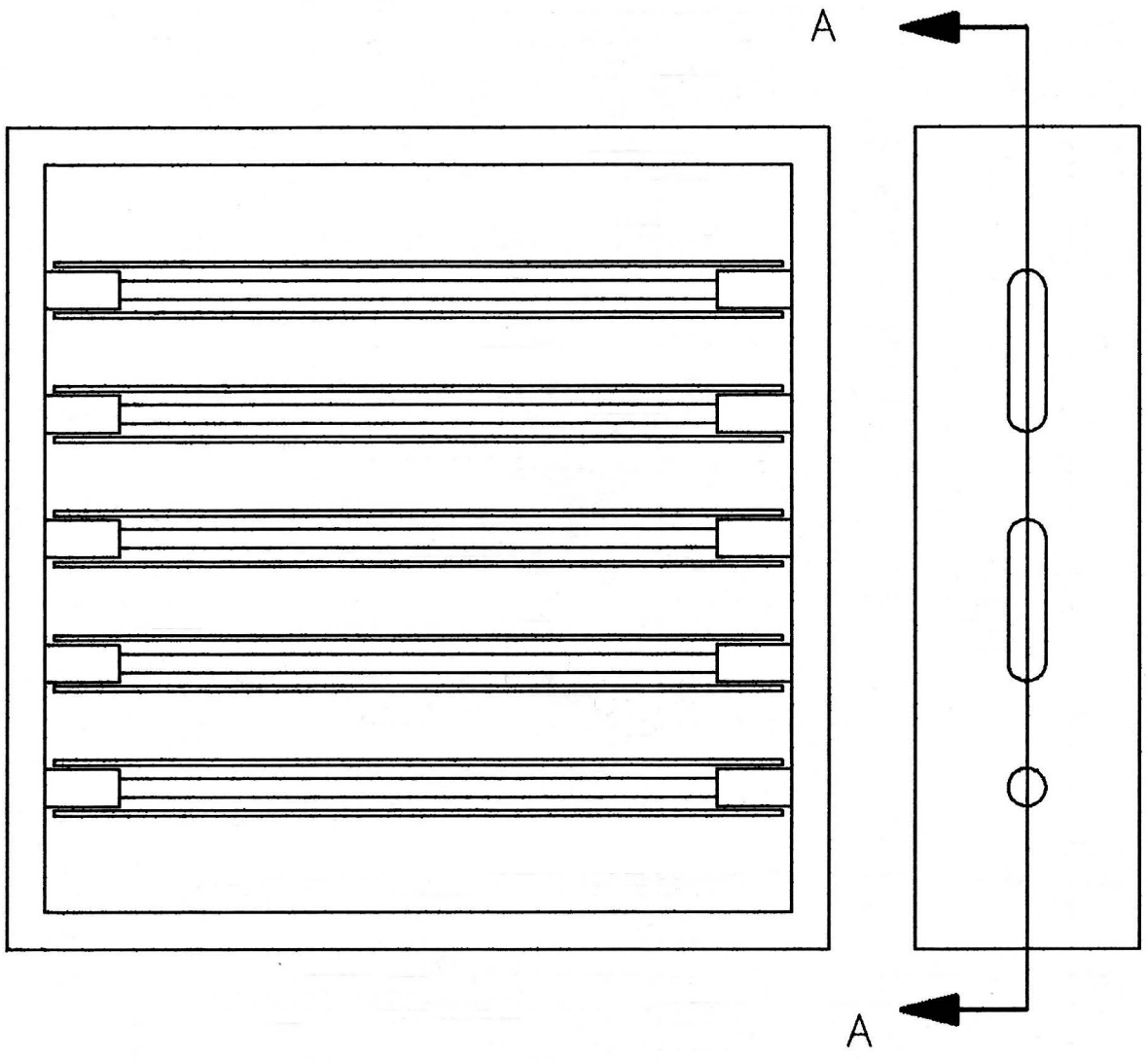
Standard Handbook of Engineering Calculations, Tyler, McGraw-Hill, New York 1972

W.W. Grainger Company Catalog, 1979

APPENDIX 1

THE FOLLOWING ARE DESIGN DRAWINGS OF THE BABY CHAMBER INCLUDING THE SUBSYSTEMS. SOME OVERSIZE DRAWINGS ARE LOCATED IN THE POCKET OF THIS FOLDER.

REV. LETTER	REVISION DESCRIPTION	DATE	BY



SECTION A-A

END VIEW

USU / CAD / CAM
COLLEGE OF ENGINEERING

TITLE

HEATER

DATE 5/25/85	SCALE 1/1.25	DWG SIZE A	SHEET 1 OF 1

DRAWN BY	DRAWING NUMBER
J.STEVENS	3

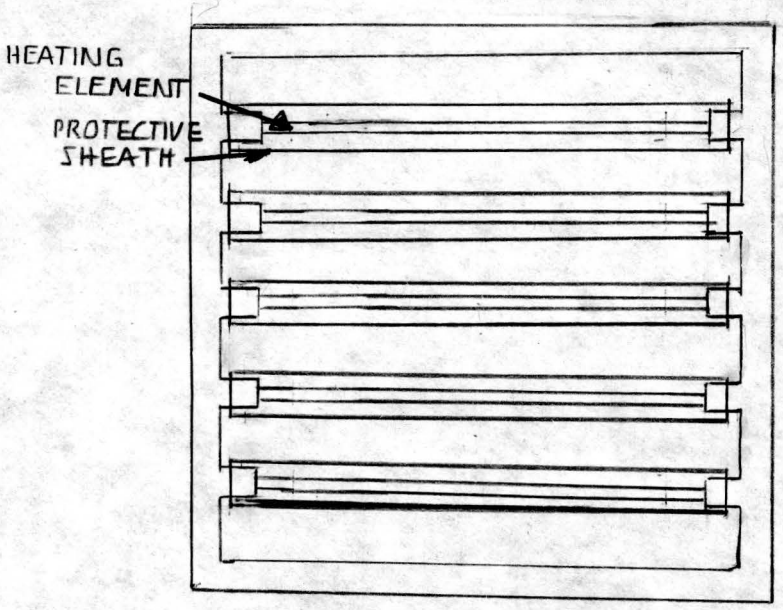
CADAM DRAWING
DO NOT REVISE MANUALLY

APPENDIX 2

THE FOLLOWING ARE MAJOR CALCULATIONS INVOLVED IN DESIGNING THE SUBSYSTEMS AND STRUCTURE OF THIS PROJECT.

Heater Analysis

HEATER



Required Heating Capacity:

maximum temperatur
in chamber = 95°F
minimum inlet temp: 40

$q = \dot{m} C_p \Delta T$ ①

$\Delta T = (95-40)\,°F = 55°F$

$C_p = .240 \frac{BTU}{lbm\,°R}$

$\dot{m} = ?$ ①

$q = \left(\frac{90}{60} \frac{ft^3}{sec}\right)(2.47)(10^{-3} \frac{lbm}{ft^3})$
$(.240 \frac{BTU}{lbm\,°R})(55°R)$
$= .053471 \frac{BTU}{sec} (3600 \frac{sec}{hr})$
$= 192.5\ BTUh$
$= 56.469\ watts$

Using Ribbon Element:

ℓ = 5 ribbon elements @ 4" long each = 20" wire = $\frac{5}{3}$ ft wire

$q_{req} = 56.469$ watts

$R = \frac{V^2}{W}$ ② $= \frac{(120V)^2}{56.469W} = 255.01\,\Omega$

$R/\ell = \frac{255.01\,\Omega}{5/3\ ft} = 153\,\Omega/ft$ + 6% more for possible compensation for protective covering

$R/\ell = (1.06)(153\,\Omega/ft) = 162.185\,\Omega/ft$
which is much too high.

Using Coils:
coils on 1/8" ceramic bar, 32 windings / inch, 5 bars

$\ell = (2\pi)(\frac{1/8}{2})(\frac{in}{winding})(32 \frac{windings}{inch})(4\ inches/bar)(5\ bars) = 251.327\ in$
$= 20.95 \frac{ft}{wire}$

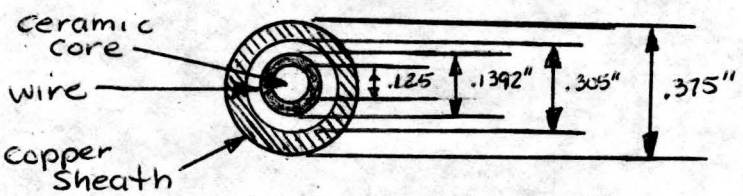
$R/\ell = 1.06\left(\frac{255.01\,\Omega}{20.95\ ft}\right) = 12.90\,\Omega/ft$

①Equations and values from Fundamentals of Fluid Mechanics
②

Wire Specification: Nichrome V Wire #33 AWG
$\phi = .0071"$ @ 12.90 Ω/ft.
6925 ft/lb. bare wire
Pelican Wire Company
6266 Taylor Road
Naples, Florida 33942
(813) 597-8555

Heat Transfer Analysis

From Fundamentals of Heat Transfer, Incropera & DeWit
Free Convection, Concentric Cylinders pgs. 453-454
cross section



At I = .5 amp, T_{wire} = 200 °F
= 93 °C
= 366 °K

Thermophysical Properties of Air, IBID, pg. 775
T_∞ = 366 °K
ρ = .9950 kg/m³
C_p = 1.009
ν = 20.92 (10⁻⁶) m²/s
k = 30.0 W/mK
α = 29.9 (10⁻⁶) m²/s
Pr = .7000
$\beta = 1/T = \frac{1}{354} = .00282$

at T_∞ = 40 °F = 4.44 °C = 277 °K
ν_∞ = 13.665 (10⁻⁶) m²/sec
α_∞ = 19.20 m²/sec
Pr_∞ = .7135

$$q' = \frac{2\pi K_{eff}}{\ln(d_o/d_i)}(T_i - T_o) \quad \text{(eqn 9-46)} \quad \text{pg. 454}$$

$$K_{eff} = .386\left(\frac{Pr}{.861+Pr}\right)^{1/4}(Ra_c^*)^{1/4}K \quad \text{eqn. 9-47 pg. 454}$$

$$Ra_c^* = \frac{(\ln(d_o/d_i))^4}{\ell^3(d_i^{-3/5} + d_o^{-3/5})} Ra_\ell \quad \text{eqn 9-48 pg. 4-54}$$

may be used for the range $10^2 \le Ra_c^* < 10^7$

$$Ra_\ell = \frac{g\beta(T_i - T_o)\ell^3}{\nu\alpha} = \frac{(9.81)(.00282)(366 - T_o)((.0254)(4))^3}{(20.92)(29.9)(10^{-12})}$$

$$= 46384(366 - T_o)$$

$$Ra_c^* = \frac{\ln(d_o/d_i)}{\ell^3\left(d_i^{-3/5}+d_o^{-3/5}\right)^5}\,Ra_\ell = \frac{\ln(.375/.1392)\,(46384\,(366-T_o))}{((4)(.0254))^3\left((.1392)(.0254)\right)^{-3/5}+\left((.375)(.0254)\right)^{-3/5}\Big)^5}$$

$$= \frac{45967.2\,(366-T_o)}{2.13506(10^5)} = .2153(366-T_o)$$

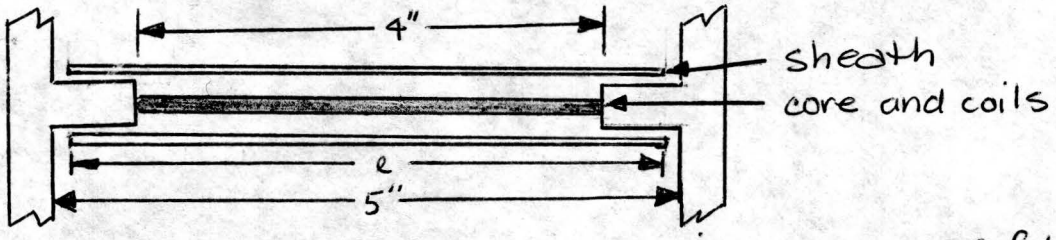
even if $T_o = 0$, (which is highly unlikely); $Ra_c^* = 78.872$

$Ra_c^* < 100$ so we will assume $T_{coil} = T_{copper\ sheath}$

$= 200°F$

Analysis of copper tubing sheath

protective covering from humidity



linear expansion of pipe in inches per 100 ft

Heating, Ventillating, and Air Conditioning, G.E. Clifford pg. 546

ΔT (°F)	Brass & Copper
160	1.70

$$\Delta\ell = \frac{1.70\ in}{100\ ft}\,\frac{(4\ in)}{12\ in/ft}$$

$= .0057$ in

$\ell_{copper\ sheath} = \underline{4.75"}$

Humidifying

$$\dot{m} = \rho A V = \rho Q = \frac{90 \text{ cfm } (.06615 \frac{lb}{ft^2})(2.205 \frac{kg}{lb})}{60 \text{ sec/min}} = .218791 \frac{kg}{sec}$$ ①

at T = 140°F

at 200°F $\dot{m} = \frac{90}{60}(2.205)(.06013) = .19888$

at 95°F $\dot{m} = \frac{90}{60}(2.205)(.07151) = .23652$

$V = 450 \text{ fpm} = \frac{450}{60}(.3048) = 2.286 \text{ m/s}$

$d = .375 \text{ in} = .375/39.37 = .009525 02 \text{ m}$

Properties of air ② at

$T_\infty = 4.44°C = 277.4°K = 40°F$

$\rho = 1.27805 \text{ kg/m}^3$

$C_p = 1.0065 \text{ KJ/kgK}$

$\mu = 172.1 (10^{-7}) \text{ Ns/m}^2$

$\nu = 13.665 (10^{-6}) \text{ m}^2/\text{s}$

$K = 24.3 (10^{-3}) \text{ W/mK}$

$\alpha = 19.2 (10^{-6}) \text{ m}^2/\text{s}$

$Pr = .7135$

$$Re_{d\infty} = \frac{(1.27805)(2.286)(.009525)}{171.1 (10^{-7})} = 1616.99$$

$T_s = 366.3 K$

$\rho = .97022 \text{ kg/m}^3$

$C_p = 1.010 \text{ KJ/kgK}$

$\mu = 212.58 (10^{-7}) \text{ Ns/m}^2$

$\nu = 22.018 (10^{-6}) \text{ m}^2/\text{s}$

$K = 30.76 (10^{-3}) \text{ W/mK}$

$\alpha = 31.58 (10^{-6}) \text{ m}^2/\text{s}$

$Pr = .698$

$$Re_{ds} = \frac{Vd}{\nu} = \frac{\rho V d}{\mu} = \frac{(.97022)(2.286)(.009525)}{(212.58)(10^{-7})} = 993.78$$

Equation 7-31 Cylinder in Cross Flow ③, page 345

$$\overline{Nu}_d = C Re_d^m Pr^n \left(\frac{Pr_\infty}{Pr_s}\right)^{1/4} \quad \text{for } .7 < Pr < 500,\ 1 < Re < 10^6$$

at T_∞

if $Pr < 10$, $n = .37$

$Pr \geq 10$, $n = .36$

Re	C	m
1-40	.75	.4
40-1000	.51	.5
$10^3 - 2(10^5)$	.26	.6
$2(10^5) - 10^6$	.076	.7

① Fundamentals of Fluid Mechanics, Flammer, Jeppson & Keed
② Heat and Mass Transfer, Incropera and Dewitt
③ Heat and Mass Transfer, Incropera and Dewitt

at $T_\infty = 40°F$

$$\overline{Nu}_d = .26(1616.99)^{.6}(.7135)^{.37}\left(\frac{.7135}{.698}\right)^{1/4} = 19,424$$

$$\overline{Nu}_d = \frac{\bar{h}d}{K} \qquad h = \frac{\overline{Nu}_d K}{d} = \frac{19,424(30.76)(10^{-3})}{.00952502\ldots} = 62.7276 \frac{W}{m^2 K}$$

$$q = hA\Delta T = hA(T_s - T_\infty)$$

$$q_{/bar} = 62.7276(\pi)(.009525)\left(\frac{4}{39.37}\right)(366.3-277.4) = 16.9539W \text{ per bar}$$

$$q_{total} = 5(q_{bar}) = 84.7697 \text{ Watts}$$

$$= 289.32 \text{ BTUh}$$

$$q = \dot{m}C_p\Delta T = \frac{289.32}{3600} = .08037 \text{ BTU/sec}$$

$$.08037 = (1.5 \tfrac{ft^3}{sec})(2.47)(10^{-3}) \tfrac{lbm}{ft^3})(.240)(T_f - 40°F)^*$$

$$T_f = \underline{\underline{130.38\ °F}}$$ in duct after it has gone through the heater

Humidification Load①

From Psychometric chart② $W_i = .01$ lbw/lbda

$W_{out} = .018$ lbw/lbda

$$H = \text{humidification load} = \frac{90 cfm(60 min/hr)}{3.5\ ?}(.018-.01)\frac{lbw}{lbda}$$

$$= 12.343 \frac{lbw}{hr}$$

$$\frac{12.343 lb/hr}{62.37 lb/ft^3} = .1979 ft^3/hr = (.1979)(7.481) = 1.481 \frac{gal}{hr}$$

From psychometric Chart and Heating, Ventillating, and Air Cond., Clifford, pg.

	ΔRH	ΔT
Filter 1	10% - 20%	130°F to 118°F
Filter 2	20% - 50%	118°F to 97.5°F

$$7 days(24 \tfrac{hrs}{day})(80\% \text{ of time in operation})(1.481 \tfrac{gal}{hr}) = 199.05 \cong 200 \text{ gal/week.}$$

$$= 26.9143 ft^3/week.$$

① Heating, Ventillating and Air Conditioning, George E. Clifford, pgs. 187-189

② Psychometric Charts are from Industrial Ventillation

* Note: I know I don't overdesign, but these values are extreme values. Actual operating requirements will probably be lower.

Comments

The unit requires quite a bit of water so it is not really feasible to have a self-contained unit (one that is filled weekly or so). It will have to be connected to household water. The inlet will have to be controlled by a valve that allows the water to come in only when it is required. A float valve is required in the reservoir to control the valve that controls the flow in.

Reservoir

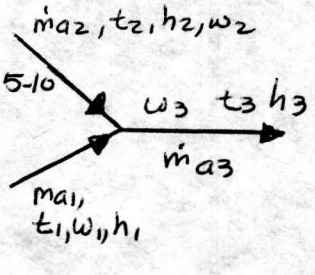
Space available 13" deep, 47½" long, 32" wide

Volume $\frac{(10.5")(47.5)(32)}{(12)^3} = 10.116$ cubic feet

This means that it would have to be filled 3 times a week, so conclusions mentioned in "Comments" above apply.

While operating,

Adiabatic mixing of 2 air streams ①



$\dot{m}_{a1} h_1 + \dot{m}_{a2} h_2 = \dot{m}_{a3} h_3$ eqn 5-10

$\dot{m}_{a1} + \dot{m}_{a2} = \dot{m}_{a3}$ eqn 5-11

$\dot{m}_{a1} \omega_1 + \dot{m}_{a2} \omega_2 = \dot{m}_{a3} \omega_3$ eqn 5-12

This defines a straight line on the psychometric chart.

Then, $t_3 = \frac{\dot{m}_{a1} t_1 + \dot{m}_{a2} t_2}{\dot{m}_{a1} + \dot{m}_{a2}}$

$\omega_3 = \frac{\dot{m}_{a1} \omega_1 + \dot{m}_{a2} \omega_2}{\dot{m}_{a1} + \dot{m}_{a2}}$ $\qquad$ $h_3 = \frac{\dot{m}_{a1} h_1 + \dot{m}_{a2} h_2}{\dot{m}_{a1} + \dot{m}_{a2}}$

① Heating, Ventillating, and Air Conditioning, A.E.Clifford pg. 174

(1) 35% of air at 40°F and ~10% rh $\omega_1 = 4.2 \frac{\text{grains}}{\text{lb}_{da}}$

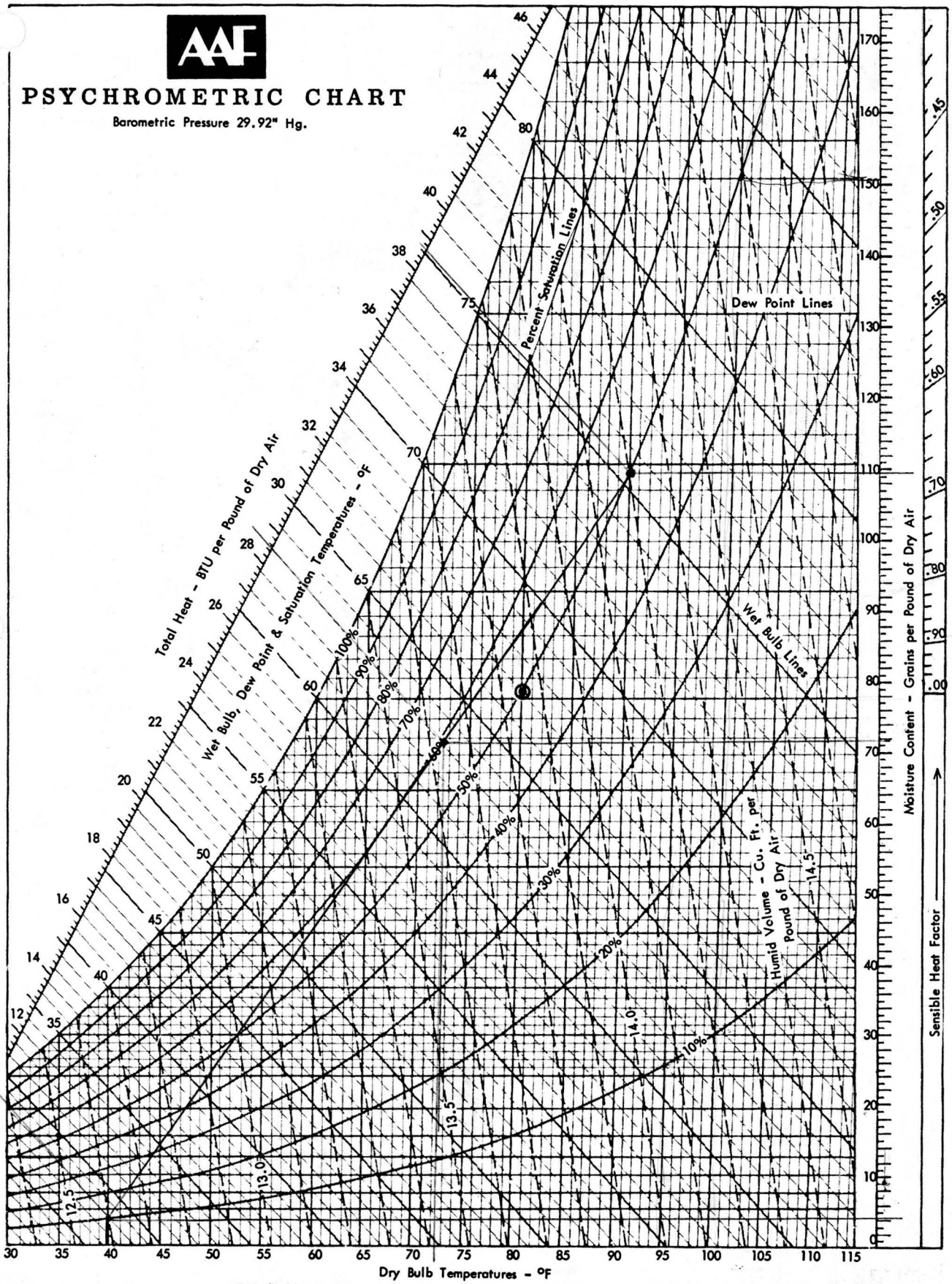
(2) 65% of air at 90°F and ~50% rh $\omega_2 = 109.5 \frac{\text{grains}}{\text{lb}_{da}}$

$$\omega_3 = .65(109.5) + .35(4.2) = 72.645 \frac{\text{grains}}{\text{lb}_{da}}$$

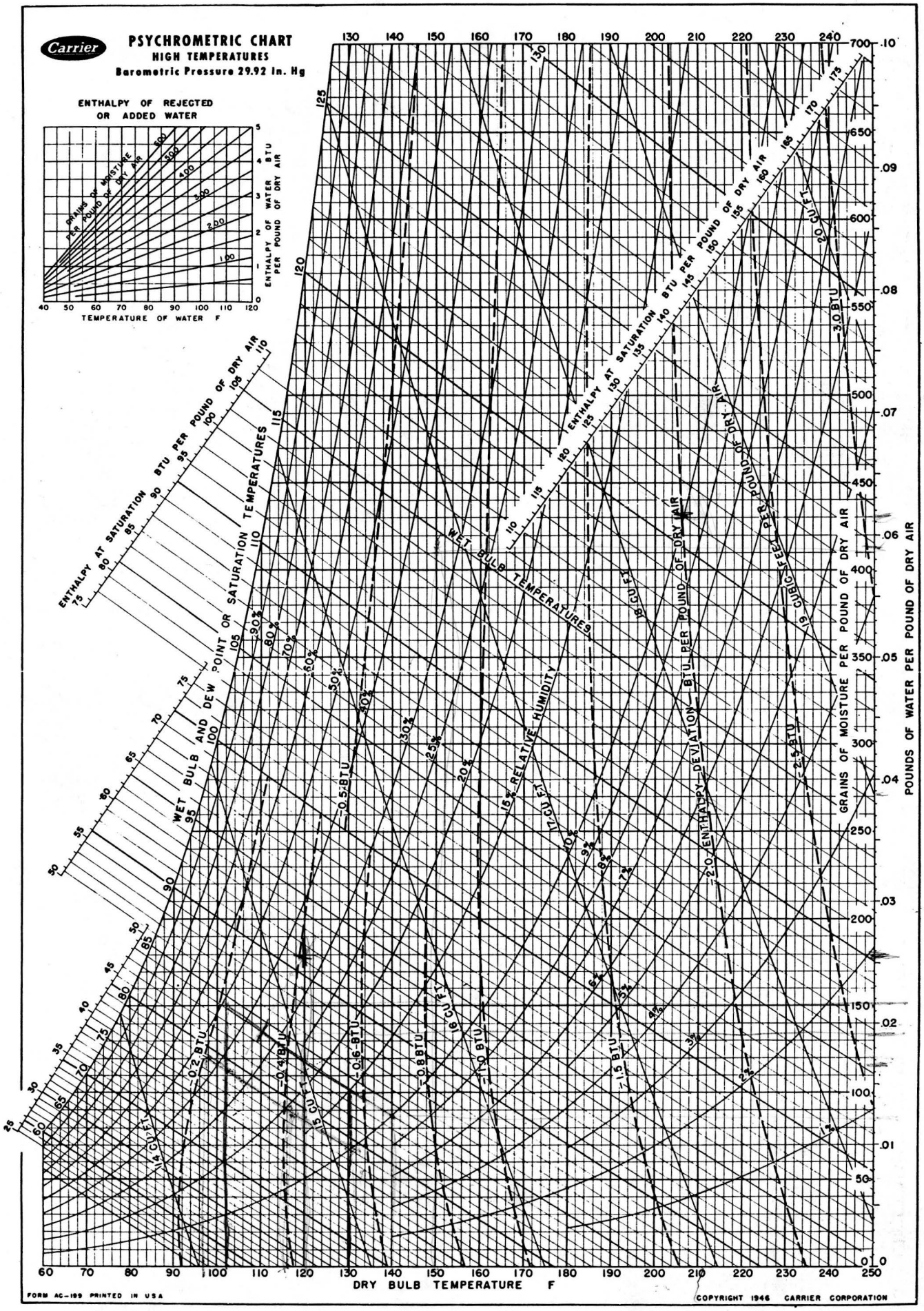
then, from the psychometric chart,

$$t_3 = 72.5\,^{\circ}\text{F}$$

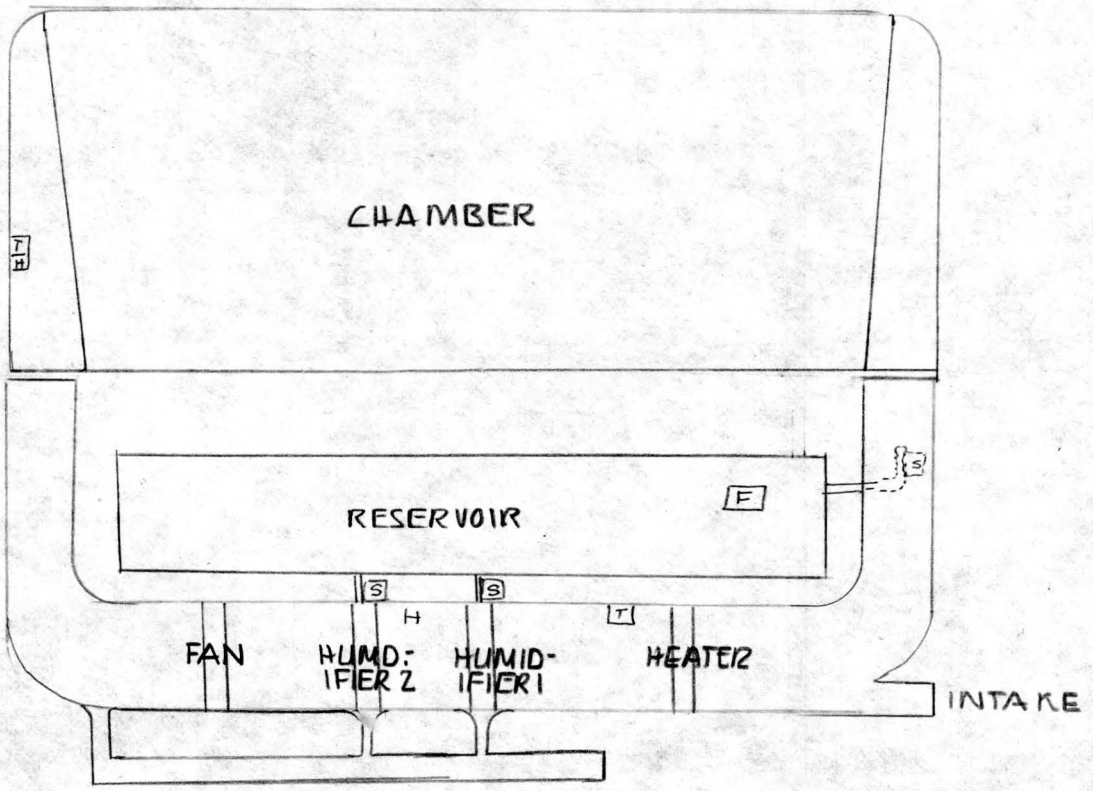
$$h_3 = 28.5 \frac{\text{BTU}}{\text{lb}_{da}}$$



Total Heat Values - ASHAE Guide
End Points - Zimmerman & Lavine


Carrier
PSYCHROMETRIC CHART
HIGH TEMPERATURES
Barometric Pressure 29.92 In. Hg
ENTHALPY OF REJECTED OR ADDED WATER
GRAINS OF MOISTURE PER POUND OF DRY AIR
ENTHALPY OF WATER BTU PER POUND OF DRY AIR
TEMPERATURE OF WATER F
ENTHALPY AT SATURATION BTU PER POUND OF DRY AIR
WET BULB AND DEW POINT OR SATURATION TEMPERATURES
WET BULB TEMPERATURES
ENTHALPY AT SATURATION BTU PER POUND OF DRY AIR
RELATIVE HUMIDITY
CUBIC FEET PER POUND OF DRY AIR
ENTHALPY-DEVIATION BTU PER POUND OF DRY AIR
GRAINS OF MOISTURE PER POUND OF DRY AIR
POUNDS OF WATER PER POUND OF DRY AIR
DRY BULB TEMPERATURE F
FORM AC-199 PRINTED IN U.S.A.
COPYRIGHT 1946 CARRIER CORPORATION

Fan Calculations



Chamber Volume $5' \times 3' \times 3' = 45$ cubic feet (ft^3) at 2 air changes per minute①

$$Q = 45 \frac{ft^3}{change} \left(2 \frac{changes}{min}\right) = 90 \frac{ft^3}{min} = 90 \text{ cfm}$$

Static Pressure Calculation

By design, cross-sectional area of the chamber
$= 3' \times 3' = 9$ sq. ft.

By design, cross-sectional area of duct at connection between the chamber and the duct.
$= \frac{4'' \times 28''}{144 \text{ in}^2/\text{ft}^2} = .778$ sq. ft.

①Industrial Ventillation

From the Standard Handbook for Mechanical Engineers, 7th Edition, pg. for coils

"the desirable face velocity usually between 450-750 fpm. The coil face area is determined by $\frac{\text{total cfm}}{\text{velocity}}$"

also "the heating effect for 1 watt is 3.413 BTUh"

From Heating, Ventillating, and Air Conditioning, George E. Clifford, pg. 701

Recommended and maximum duct velocities

Designation	Recommended velocity fpm	maximum velocity, fpm
Outside Air Intakes[a]	500	800
Filters[a]	250	300
Heating Coils[a]	450	500

[a] These velocities are for total free area, not net free area.

Duct Size using $V = Q/A$

Q (cfm)	Edge length of square duct (in)	Area (ft^2)	velocity (fpm)
90	4.5	.140625	640
	4.75	.156684	574
	5.0	.173611	518.4
	5.3125 (5 5/16)	.195991	459.2
	5.375 (5 3/8)	.200629	448.6
	5.25	.191406	470.20
	5.50	.210069	428.43
	5.75	.229601	391.99
	6.00	.250000	360.00
	6.25	.271267	331.78
	6.5	.293043	306.75
	6.75	.316406	284.49
	7.0	.340278	264.49
	7.1875	.35875	

Duct $5\frac{3}{8}" \times 5\frac{3}{8}" = .200629\ ft^2$

$V = 449\ fpm \cong 450\ fpm$

Expansions and Contractions

$4" \times 5\frac{3}{8}"$ to $4" \times 28"$ in 15" of height

$A_{ave} = 9.6875" \times 4" = 38.87\ in^2 = .769097\ ft^2$

$$V_{ave} = Q/A_{ave} = \frac{90}{.769097} = 334.5\ fpm$$

Chamber

$A_{ave} = 3' \times 3' = 9\ sq.\ ft.$ $V_{ave} = \frac{90 cfm}{9\ ft^2} = 10\ fpm$

Static Pressure Analysis

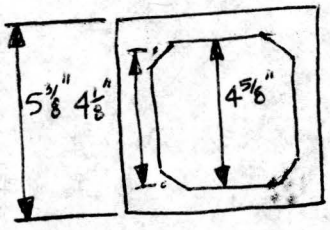
		V (fpm)	C_o	h_L
Intake Louver	1.375" x 6"	450 fpm		.00315

h_L source:

2 Filters for humidifiers	450 fpm		.1200

h_L source:

fan contraction (sudden)



$\frac{A_o}{A_1} = \frac{(4.625)^2}{(5.375)^2} = .74$ 450 .125 .00158

Source: Table 14-6, pg. 715 Heating, Ventillating, and Air Conditioning, G. Clifford, 1984

fan expansion (sudden) 450 .025 .00032

$\theta = 180°$ $\frac{A_o}{A_1} = .74$ $C_o = .025$

Table 14-5, pg. 714
IBID

90° Elbow 450 .30216 .00381

$r/w = \frac{4.6875}{5.375} = .87209$

$H/w = 1.0$

$C_o = .30216$

Table 14-3, pg. 713
IBID

contraction in elbow 450 .005 .00006

$\theta = 13.07°$ $\frac{A_o}{A_1} = \frac{(5.375)(4)}{(5.375)(5.375)} = .7442$

Table 14-6

gradual expansion 334 .69 056 .0048

$\theta = 124$ $\frac{A_o}{A_1} = .192$

$C_o\left(\frac{V}{4005}\right)^2 + \left(\frac{V}{4005}\right)^2 = h_L$

$V = 450$ fpm $V = 334$ fpm $V = 10$ fpm

$\left(\frac{V}{4005}\right)^2 = \left(\frac{450}{4005}\right)^2 = .01262$ $\frac{V^2}{4005^2} = \left(\frac{334}{4005}\right)^2 = .00695$ $\frac{V^2}{4005^2} = \left(\frac{10}{4005}\right)^2 = .00001$

	V	C_o	h_L in. water
90° Turn and holes	10	2(4.068)	.00293
Gradual Contraction	334	.01	.00007
90° Turn	450	.20313	.00256
			.14216

$A_1 = \frac{28(32)}{36} = 24.88$

$A_o = 3.14156$

$\frac{A_o}{A_1} = .126$

$C_o = 36(.113)$

$= 4.068$

$\theta = 124$ $\frac{A_o}{A_1} = .192$

$H/W = \frac{5.375}{4} = 1.34375$

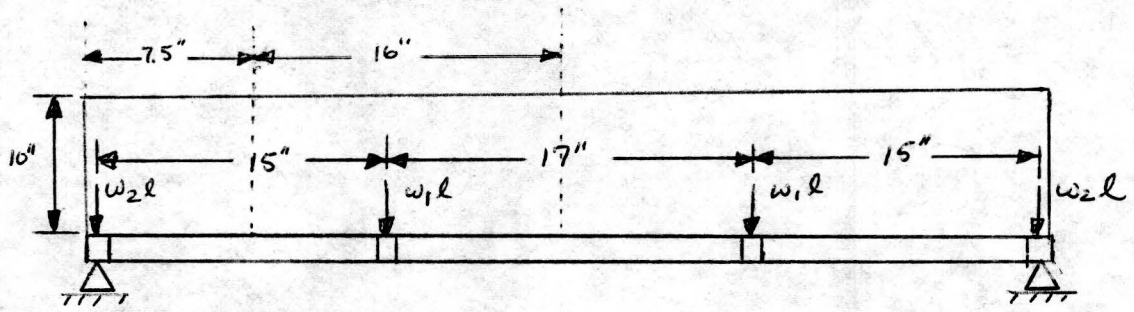
$r/w = 4/4 = 1$

Fan: Pamotor 4600X Series

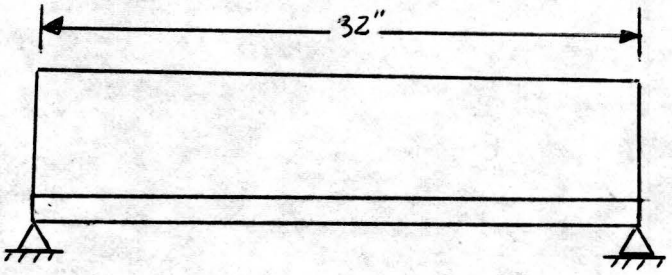
Local Supplier: Elmer Electronics
6777 E. 50th Avenue
Commerce City, CO, 80022
(303) 287-9611

Structural Analysis

Reservoir support



FRONT VIEW - RESERVOIR



SIDE VIEW

$$w_1 = 62.37 \frac{lb}{ft^3}\left(\frac{10"(16")}{144 in^2/ft^2}\right) = 69.3 \ lb/ft = 5.775 \ lb/in$$

$$w_2 = 62.37 \frac{(10)(7.5)}{144} = 32.48 \frac{lb}{ft} = 2.707 \ lb/in$$

side view:

Beam 2"x4" wood stud $I = \frac{bh^3}{12} = \frac{2(4)}{12} = 10.667 \ in^4$

$E = 1.5(10^6)$ psi

$$y_{max} = \frac{-wl^4}{384EI} \ @ \ l/2$$

$$y_{max} = \frac{-5.775(32)^4}{384(1.5)(10^6)(10.667)}$$

$= -.00099$ in

$\cong .001$ in

which is negligible

$$\sigma = \frac{mc}{I}$$

$$m = \frac{wl^2}{2} = \frac{5.775(32)^2}{2} = 2956.8 \frac{lb}{in}$$

$$\sigma = \frac{(2956.8)(1)}{10.667} = 277.19 \text{ psi}$$

which is well under $1.5(10^6)$ psi.

could use steel bars

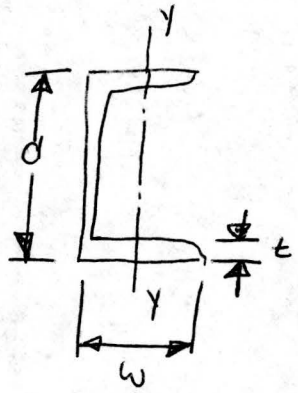
Standard Channel

safety factor of 5

$$\sigma_{max} = \frac{30(10^6)}{5} = 6(10^6)$$

$$\sigma = \frac{2956.8(1)}{I} = 6.0(10^6) \qquad I = .0004928$$

smallest standard channel C3x4.1



Y-Y

weight 4.1 lb/ft

depth (d) 3.00 in

width (w) 1.41 in

thickness (t) .273 in

I .20 in^4

$$\sigma = \frac{(2956.8)(1)}{.2} = 1.478(10^4) < 6(10^6) = \sigma_{max}$$

$$y_{max} = \frac{-5,775(32)^4}{384(30)(10^6)(.2)} = .00263 \text{ in}$$

This is the major load consideration. Refer to structural drawing for other structure supports.

APPENDIX 3

THE FOLLOWING IS MANUFACTURERS DATA WHICH WAS USED IN THE DESIGN OF THIS PROJECT. ALSO INCLUDED ARE SOME OF THE SAFETY REGULATIONS TAKEN INTO CONSIDERATION WHILE WORKING ON THIS PROJECT.

PELICAN WIRE COMPANY INC.

DEAR MIKE: WE CAN SUPPLY NICHROME SOLID

6266 TAYLOR ROAD

NAPLES, FLORIDA 33942

813/597-8555

Here it is — Warm Florida Sunshine and another Stock List from the Pelican Wire Company!

Larry G. Bill

PRESIDENT

CUSTOM INSULATING - LARGE INVENTORY - IMMEDIATE DELIVERY

PELICAN WIRE CO. INC.
STOCK LIST
08/23/84

A. W. G.	DIAMETER	TYPE OF WIRE	OHMS PER FT.	QUANTITY LBS.	PRICE LBS.	ITEM NO.
24	.0201	NICHROME V HARD DRAWN	1.609	30.0	10.50	260
25	.0197	NICHROME V	2.029	55.97	14.96	265
26	.0159	NICHROME V	2.571	19.99	15.51	270
27	.0142	NICHROME V	3.228	1.96	16.21	275
28	.0126	NICHROME V	4.090	16.56	16.61	280
29	.0113	NICHROME V	5.090	22.0	18.62	285
30	.010	NICHROME V	6.500	31.24	20.16	290
31	.0089	NICHROME V	8.206	1.75	22.10	295
32	.008	NICHROME V	10.16	1.63	24.10	300
33	.0071	NICHROME V	12.90	3.59	27.25	305
34	.0063	NICHROME V	16.37	5.7	28.70	310
35	.0056	NICHROME V	20.72	1.5	30.57	315
36	.005	NICHROME V	26.00	15.0	34.34	320
37	.0045	NICHROME V	32.09	12.06	36.75	325
38	.004	NICHROME V	40.62	5.7	46.20	330
39	.0035	NICHROME V	53.06	4.79	49.35	335
42	.0025	NICHROME V	104	3.0	82.95	340
43	.00225	NICHROME V	128.5	.6	107.33	345
44	.002	NICHROME V	162.5	2.18	127.05	350
46	.0015	NICHROME V	288.9	.9	229.95	355
10	.102	ADVANCE	.02826	575	8.47	360
11	.091	ADVANCE	.03550	286	8.47	365
	.081	ADVANCE	.04481	23.86	10.89	370
	.064	ADVANCE	.07178	89.07	11.36	375
16	.051	ADVANCE	.113	16.85	11.36	380
18	.040	ADVANCE	.1837	9.89	11.36	385
19	.036	ADVANCE	.227	32.0	11.36	390
20	.0325	ADVANCE	.2871	6.58	11.36	395
21	.0285	ADVANCE	.3619	30.0	11.36	400
22	.0253	ADVANCE	.4557	30.0	11.36	405
23	.0226	ADVANCE	.5756	42.99	11.77	410
24	.0201	ADVANCE	.7277	36.58	11.97	415
25	.0179	ADVANCE	.9176	37.0	12.34	420
26	.0159	ADVANCE	1.163	10.0	12.73	425
27	.0142	ADVANCE	1.458	20.3	13.29	430
28	.0126	ADVANCE	1.852	36.19	14.46	435
29	.0113	ADVANCE	2.302	13.67	14.86	440
30	.010	ADVANCE	2.94	11.0	15.43	445
31	.0089	ADVANCE	3.722	6.1	16.18	447
32	.008	ADVANCE	4.594	14.42	17.59	450
33	.0071	ADVANCE	5.833	12.39	21.44	453
34	.0063	ADVANCE	7.408	20.0	21.58	455
35	.0056	ADVANCE	9.375	3.0	23.31	460
36	.005	ADVANCE	11.76	9.9	25.28	465
37	.0045	ADVANCE	14.52	6.0	30.85	470
38	.004	ADVANCE	18.37	12.0	37.66	475
40	.0031	ADVANCE	30.60	3.0	61.07	480
41	.00275	ADVANCE	38.88	2.5	82.95	485
	.002	ADVANCE	73.50	0.5	157.50	490
1o	.040	MIDOHM	.1125	19.0	13.82	495
20	.032	MIDOHM	.1758	43.0	14.18	500
22	.0253	MIDOHM	.2812	28.1	14.53	505
24	.0201	MIDOHM	.4455	42.0	15.08	510

PAMOTOR
ONE OF THE PURDY GROUP OF COMPANIES

4500X Series

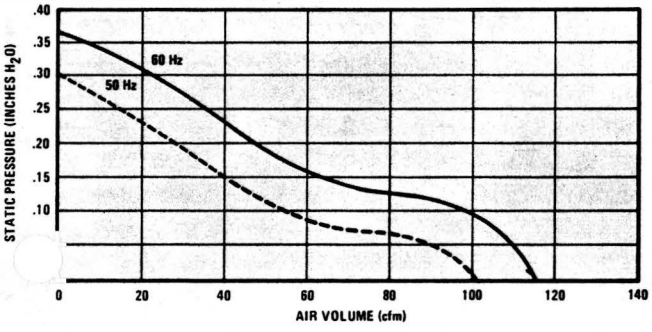
CFM: 115

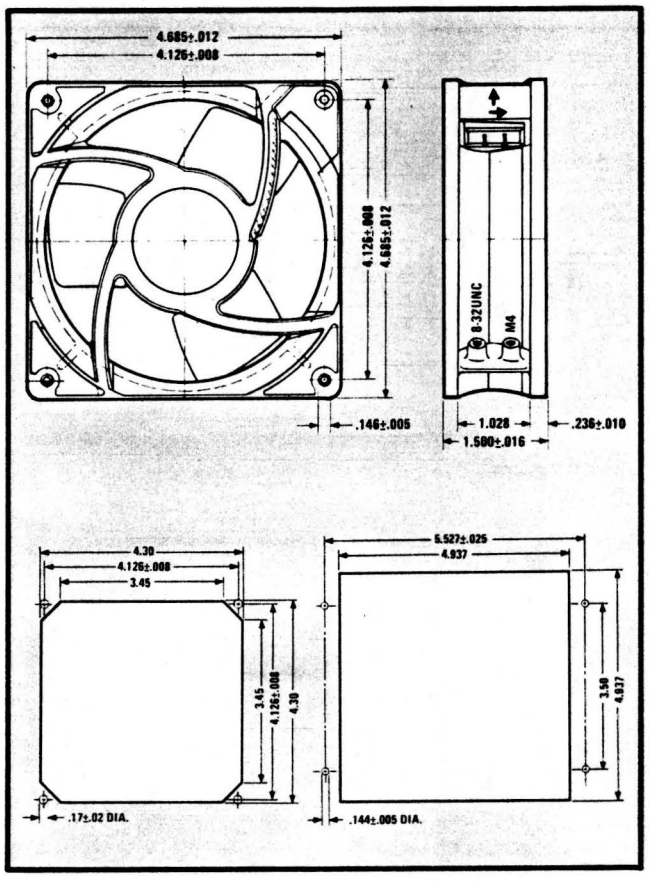
SIZE: 4.68" Square x 1.50" Depth

FEATURES

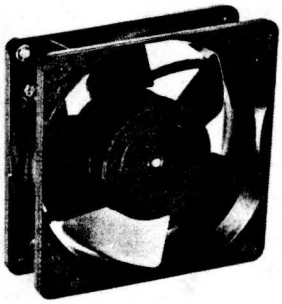
- UL recognized - Yellow Card E41168
- Designed to meet C.S.A. and I.E.C. standards
- Uni-housing
- Lighter weight
- Increased reliability and performance
- Improved bearing system
- Two ground positions, U.S. and Metric

Model Number	Bearing System	Voltage (ac)	Frequency (Hz)	Input Power (Watts)	Air Flow (cfm)	Speed (rpm)	Weight (ounces)	Noise Level dB (A)	Noise Level dB (SIL)
4500X	Sleeve, Broached Sintered Iron	115	50/60	17	115	3100	18	44	31
4506X	Ball Bearing	115	50/60	19	115	3250	18	48	33
4550X	Sleeve, Broached Sintered Iron	220	50/60	17	115	3100	18	44	31
4556X	Ball Bearing	220	50/60	19	115	3250	18	48	33





4600X Series



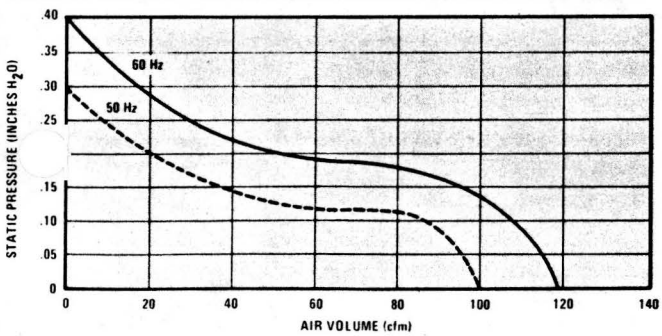
CFM: 120

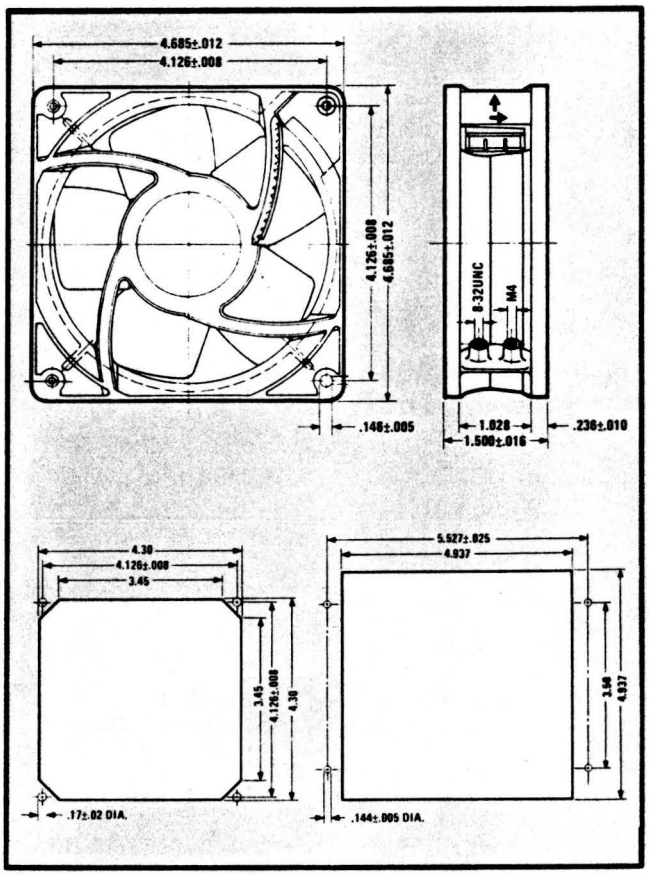
SIZE: 4.68" Square x 1.50" Depth

FEATURES

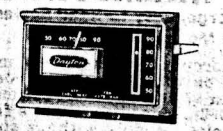
- UL recognized - Yellow Card E41168
- Designed to meet C.S.A. and I.E.C. standards
- Uni-housing
- Lighter weight
- Increased reliability and performance
- Improved bearing system
- Two ground positions, U.S. and Metric

Model Number	Bearing System	Voltage (ac)	Frequency (Hz)	Input Power (Watts)	Air Flow (cfm)	Speed (rpm)	Weight (ounces)	Noise Level dB (A)	Noise Level dB (SIL)
4600X	Sleeve, Broached Sintered Iron	115	50/60	18	120	3100	18	46	34
4650X	Sleeve, Broached Sintered Iron	220	50/60	18	120	3100	18	46	34





24V HEATING/COOLING THERMOSTAT

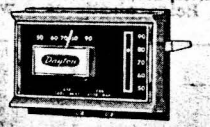


Mercury Switch Type. No Sub-Base or Mounting Bracket Required

$11.88 Full-feature, economical thermostat for low-voltage control of all types of heating/cooling systems. Single-unit construction and slide-in terminals speed installation. Sealed mercury switch. Convenient Cool-Off-Heat and fan Auto-On switches. 50° to 90°F control range differential. 50°-90° thermometer. Adjustable heat anticipator, 0.18 to 1.2 amps. Fixed cooling anticipation. 1°F differential on heating, 1½°F on cooling. Beige case, bronze and gold face plate. 3¾ W x 2¾ H x 1¼" D. Shpg. wt. 5 oz.

No. 2E273. Heating/Cooling Thermostat. Retail $23.76. Each.....**$11.88**

24V HEATING/COOLING THERMOSTAT

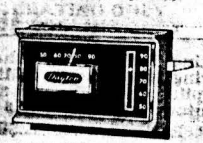


Snap-Action Type. No Sub-Base or Mounting Bracket Required

$11.68 Full-feature, economical thermostat for low-voltage control of all types of heating/cooling systems. Single-unit construction. Slide-in terminals. Snap-action switch—no leveling required. Convenient Cool-Off-Heat and fan Auto-On switches. 50° to 90°F control range differential. 50°-90° thermometer. Adjustable heat anticipator, 0.18 to 1.2 amps. Fixed cooling anticipation. 1°F differential on heating, 1½°F on cooling. Beige case, bronze and gold face plate. 3¾ W x 2¾ H x 1¼" D. Shpg. wt. 5 oz.

No. 2E514. Heating/Cooling Thermostat. Retail $23.36. Each.....**$11.68**

24V SNAP-ACTION HEATING THERMOSTAT

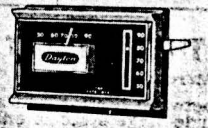


No Leveling Required. Adjustable Anticipator

$6.20 Economical low-voltage thermostat for 24V control of gas, oil or electric heating systems. Control circuit closes on temperature drop. Temperature selector has 50°-90°F range. 1°F fixed differential. 50°-90° thermometer. Adjustable heat anticipator, 0.18 to 1.2 amp. Slide-in terminals. Beige case, bronze and gold face plate. 3¾ W x 2¾ H x 1¼" D. Shpg. wt. 8 oz.

No. 2E156. Heating Thermostat. Retail $12.40. Each.....**$6.20**

24V SNAP-ACTION COOLING THERMOSTAT

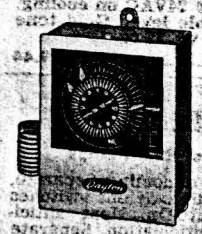


No Leveling Required. Auto-On Fan Switch

$7.51 Economical low-voltage thermostat for 24V control of cooling systems. Control circuit closes on temperature rise. Has Auto-On fan switch. Temperature selector has 50° to 90°F range. 1½°F differential. 50°-90°F thermometer. Fixed cooling anticipation. Slide-in terminals for easy wiring. Beige case, bronze and gold face plate. 3¾ W x 2¾ H x 1¼" D. Shpg. wt. 8 oz.

No. 2E278. Cooling Thermostat. Retail $15.02. Each.....**$7.51**

TEMPERATURE SETBACK CONTROL



For Heating Only. Operates with Existing Thermostat. 24VAC
Automatically Raises or Lowers Temperature. Reduces Fuel Costs

$27.22 Unique control combines a temperature sensor with a 24 hour recycling timer to provide an economical means of automatic heating temperature setback. Utilizes existing low voltage room thermostat and 24VAC power transformer. Unit automatically switches control of existing thermostat to its own built-in thermostat according to setting of the timer. Suitable for residential or commercial systems. Timer, with adjustable trippers, permits selection of nighttime setback, daytime setback or both. Timer also has manual override switch. Fast-acting temperature sensing element with 3/4°F differential and wide-range set-point adjustment. Large, easy-to-read-and-set timer dial with 1/2 hour increments. Easy to install—no batteries or line voltage wiring. Requires 24VAC @ 10VA. Silver beige case, brown face plate, black and white dial. 7 H x 5⅞ W x 3" D. Shpg. wt. 2 lbs.

No. 2E452. Temperature setback control. Retail $54.44. Each.....**$27.22**

PHONE YOUR ORDERS TO GRAINGER'S FOR TIME SAVING PICK-UP
WE'LL HAVE THE ITEMS READY WHEN YOUR TRUCK ARRIVES

24-VOLT MULTI-PURPOSE THERMOSTAT

40 to 80°F Range. Lockable Set Point Adjustment. SPST Mercury Switch

$9.53 Minimum setting of 40°F makes this thermostat suitable for heating systems requiring control just above freezing. Also has adjustable locking device that can lock temperature set-point lever at a specific setting or provide a minimum or maximum setting stop. Sealed SPST mercury switch type, for heating only. Attractive, instrument-style, easy-to-read dial. 32 to 108°F bimetal thermometer. Convenient slide lever set-point adjustment with 35 to 80°F range. Wide-range, adjustable anticipation of 0.15 to 1.0A handles all normal 24V installations. Beige case, gold and black face. Shpg. wt. 12 oz.

No. 2E466. Multi-Purpose Thermostat. Retail $19.06. Each.....**$9.53**

HEATING-VENTILATING CONTROL

For Farm and Commercial Applications, Single and Two-Stage Controls

$19.10 **No. 2E206** Extremely sensitive to temperature change. Switches on temperature rise or drop. Dial range adj. from 30° to 110°F. 3½°F fixed differential. SPDT switch rated at 16 amps, 120V, 60 Hz inductive load—2500 watts. 22 amp non-inductive (heating), 8 amps, 240V, 60 Hz, inductive load—5000 watts, 22 amp non-inductive. Compact, helical temperature sensing element. NEMA 1 enclosure. Corrosion resistant. Shpg. wt. 1 lb. UL listed.

No. 2E206. Single-Stage Thermostat. Retail $45.00. Each.....**$19.10**

TWO-STAGE THERMOSTAT for controlling 2-speed ventilating fans; two exhaust fan applications for combination of heating and ventilating or cooling systems. Two separate SPDT switches with one switch operating 3°F higher than second switch. Range adj. from 30° to 110°F. Other specifications same as above. Shpg. wt. 1 lb. UL listed.

No. 2E207. Two-Stage Thermostat. Retail $68.00. Each.....**$28.90**

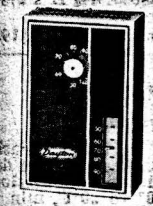
THERMOSTAT FOR PORTABLE HEATERS

SPST, Snap-Action Type. 6 Ft. Extension Cord, Hanging Chain

$23.52 Dayton line voltage thermostat designed for controlling gas and oil-fired, fan-forced portable space heaters on farms, construction sites and in industrial applications. Helps conserve fuel, maintain even temperature. Has six-foot HSJ cord set with 3-prong "series" plug. User suspends thermostat by chain provided, plugs thermostat cord into 115V receptacle, plugs heater into other end of thermostat "series" plug. Enclosed SPST, snap-action contacts. Adjustable, 35 to 95°F, with "No Heat" position that allows turning heater off without disconnecting thermostat. Fixed 3½° differential. Rated 15 amps @ 120VAC inductive, 90 locked rotor amps; 1800 watts, 120VAC non-inductive; 125VA, 24/120VAC, pilot duty. Steel case, 2⅛ W, 5½ H, 2⅝" D. Gray finish. Shpg. wt. 1½ lbs.

No. 2E535. Thermostat. Retail $56.95. Each.....**$23.52**

MULTI-PURPOSE LINE VOLTAGE THERMOSTAT



SPDT for Heating and/or Cooling. Can Be Made Tamper-Proof

$29.74 Heavy-duty thermostat for controlling unit heaters, fan coils, unitary coolers, refrigerating equipment, etc. Versatile unit can be set up for use three ways: (1) for external knob adjustment over entire range, (2) for external knob adjustment over restricted range by setting internal limit stops, (3) internal adjustment only by removing cover. Removable adjustment knob allows external adjustment by authorized person only. Includes blank face plate to cover set point scale and thermometer, if desired. Features fast-acting hydraulic sensing element and dust-proof switch contacts. 40 to 90°F (4.4 to 32.2°C) adjustment range. Also has internal set point dial calibrated in °F and °C. 2°F differential on heating, 3.5°F on cooling. Electrical rating: 16A @ 120VAC and 8A @ 240VAC for heating: 8A @ 120-240VAC for cooling; non-inductive heating rating is 22A @ 120-270VAC. Silver beige case with two-tone brown face plate. 4$^{9}/_{16}$H x 2$^{13}/_{16}$W x 1$^{13}/_{16}$"D. UL listed. Shpg. wt. 1 lb.

No. 2E503. Thermostat. Retail $59.50. Each.....**$29.74**

(f) Conditions under which guards, isolation, or insulation may be substituted for grounding.

(g) Connections for lightning arresters.

Systems and circuit conductors are grounded to limit voltages due to lightning, line surges, or unintentional contact with higher voltage lines, and to stabilize the voltage to ground during normal operation. Systems and circuit conductors are solidly grounded to facilitate overcurrent device operation in case of ground faults.

Conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, are grounded to limit the voltage to ground on these materials and to facilitate overcurrent device operation in case of ground faults. See Section 110-10.

250-2. Application of Other Articles. In other articles applying to particular cases of installation of conductors and equipment, there are requirements that are in addition to those of this article or are modifications of them:

	Article	Section
Appliances		422-16
Branch Circuits		210-5
		210-6
		210-7
Cablebus		365-9
Circuits and Equipment Operating at Less Than 50 Volts	720	
Class 1, Class 2, and Class 3 Circuits		725-20
		725-42
Communications Circuits	800	
Community Antenna Television and Radio Distribution Systems		820-7
		820-22
		820-23
Conductors	310	
Conductors (Grounded)	200	
Cranes and Hoists	610	
Data Processing Systems		645-4
Electrically Driven or Controlled Irrigation Machines		675-8
		675-9
		675-10
		675-11
Electrical Floor Assemblies		366-14
Electric Signs and Outline Lighting	600	
Electrolytic Cells	668	
Elevators, Dumbwaiters, Escalators, and Moving Walks	620	
Fire Protective Signaling Systems		760-6
Fixed Electric Heating Equipment for Pipeline and Vessels		427-26
Fixed Electric Space Heating Equipment		424-14
Fixed Outdoor Electric De-Icing and Snow-Melting Equipment		426-28

	Article	Section
Fixtures and Lighting Equipment		410-17
		410-18
		410-19
		410-20
		410-21
Flexible Cords		400-22
		400-23
Generators		445-8
Grounding-Type Receptacles (Outlets)		210-7
Hazardous Locations	500-517	
Health Care Facilities	517	
Induction and Dielectric Heating Equipment	665	
Lighting Fixtures, Lampholders, Lamp Receptacles, and Rosettes	410	
Marinas and Boatyards		555-7
Metalworking Machine Tools	670	
Mobile Homes and Mobile Home Parks	550	
Motion Picture and Television Studios and Similar Locations		530-20
		530-66
Motors, Motor Circuits, and Controllers	430	
Organs	650	
Outlet, Switch and Junction Boxes, and Fittings		370-4
		370-15
Panelboards		384-27
Radio and Television Equipment	810	
Receptacles and Attachment Plugs		410-58
Recreational Vehicles and Recreational Vehicle Parks	551	
Services	230	
Service Equipment		230-63
Sound Recording and Similar Equipment		640-4
Swimming Pools, Fountains and Similar Installations	680	
Switchboards and Panelboards		384-3(c)
		384-11
Switches		380-1
		380-12
Theaters and Similar Locations		520-81
Transformers and Transformer Vaults		450-9
X-ray Equipment	660	517-140

B. Circuit and System Grounding

250-3. Direct-Current Systems.

(a) Two-Wire Direct Current Systems. Two-wire DC systems supplying premises wiring shall be grounded.

Exception No. 1: A system equipped with a ground detector and supplying only industrial equipment in limited areas.

Exception No. 2: A system operating at 50 volts or less between conductors.

Exception No. 3: A system operating at over 300 volts between conductors.

(c) Marking. Fuses shall be plainly marked, either by printing on the fuse barrel or by a label attached to the barrel, showing the following: (1) Ampere rating; (2) Voltage rating; (3) Interrupting rating where other than 10,000 amperes; (4) "Current Limiting" where applicable; (5) The name or trademark of the manufacturer.

Exception: Interrupting rating marking shall not be required on fuses used for supplementary protection.

240-61. Classification. Cartridge fuses and fuseholders shall be classified as follows:

Not Over 250 Volts	Not Over 300 Volts	Not Over 600 Volts
0- 30	0- 30	0- 30
31- 60	31- 60	31- 60
61- 100	61- 100	61- 100
101- 200	101- 200	101- 200
201- 400	201- 400	201- 400
401- 600	401- 600	401- 600
601- 800	601- 800	601- 800
801-1200	801-1200	801-1200
1201-1600	1201-1600	1201-1600
1601-2000	1601-2000	1601-2000
2001-2500	2001-2500	2001-2500
2501-3000	2501-3000	2501-3000
3001-4000	3001-4000	3001-4000
4001-5000	4001-5000	4001-5000
5001-6000	5001-6000	5001-6000

Fuses shall be permitted to be used for voltages at or below their voltage ratings.

Exception No. 1: Fuses and fuseholders larger than 6000 amperes shall be permitted when approved for the purpose.

Exception No. 2: Fuses and fuseholders of other voltages shall be permitted.

G. Circuit Breakers

240-80. Method of Operation. Circuit breakers shall be trip free and capable of being closed and opened by manual operation. Their normal method of operation by other than manual means such as electrical or pneumatic shall be permitted if means for manual operation is also provided.

240-81. Indicating. Circuit breakers shall clearly indicate whether they are in the open "off" or closed "on" position.

Where circuit breaker handles on switchboards are operated vertically rather than rotationally or horizontally, the up position of the handle shall be the "on" position.

240-82. Nontamperable. A circuit breaker shall be of such design that any alteration of its trip point (calibration) or the time required for its operation will require dismantling of the device or breaking of a seal for other than intended adjustments.

240-83. Marking.

(a) Durable and Visible. Circuit breakers shall be marked with their rating in a manner that will be durable and visible after installation. Such marking shall be required to be visible after removal of a trim or cover.

(b) Location. Circuit breakers rated at 100 amperes or less and 600 volts or less shall have the ampere rating molded, stamped, etched, or similarly marked into their handles or escutcheon areas.

(c) Interrupting Rating. Every circuit breaker having an interrupting rating other than 5000 amperes shall have its interrupting rating shown on the circuit breaker.

Exception: Interrupting rating marking shall not be required on circuit breakers used for supplementary protection.

(d) Circuit Breakers Used As Switches. Where used as switches in 120 volt, fluorescent lighting circuits, circuit breakers shall be approved for the purpose and shall be marked "SWD."

H. Overcurrent Protection Over 600 Volts, Nominal

240-100. Feeders. Feeders shall have a short-circuit protective device in each ungrounded conductor or comply with Section 230-208(d)(2) or (d)(3). The protective device(s) shall be capable of detecting and interrupting all values of current which can occur at their location in excess of their trip setting or melting point. In no case shall the fuse rating in continuous amperes exceed three times, or the long time trip element setting of a breaker six times, the ampacity of the conductor.

The operating time of the protective device, the available short-circuit current, and the conductor used will need to be coordinated to prevent damaging or dangerous temperatures in conductors or conductor insulation under short-circuit conditions.

240-101. Branch Circuits. Branch circuits shall have a short-circuit protective device in each ungrounded conductor or comply with Section 230-208(d)(2) or (d)(3). The protective device(s) shall be capable of detecting and interrupting all values of current which can occur at their location in excess of their trip setting or melting point.

ARTICLE 250 – GROUNDING

A. General

250-1. Scope. This article covers general requirements for grounding and bonding of electrical installations, and specific requirements in (a) through (g) below.

(a) Systems, circuits, and equipment required, permitted, or not permitted to be grounded.

(b) Circuit conductor to be grounded on grounded systems.

(c) Location of grounding connections.

(d) Types and sizes of grounding and bonding conductors and electrodes.

(e) Methods of grounding and bonding.

Exception No. 4: A rectifier-derived DC system supplied from an AC system complying with Section 250-5.

Exception No. 5: DC fire protective signaling circuits having a maximum current of 0.030 amperes as specified in Article 760, Part C.

(b) Three-Wire Direct-Current Systems. The neutral conductor of all 3-wire DC systems supplying premises wiring shall be grounded.

250-5. Alternating-Current Circuits and Systems to Be Grounded. AC circuits and systems shall be grounded as provided for in (a), (b), (c), or (d) below. Other circuits and systems shall be permitted to be grounded.

(a) Alternating-Current Circuits of Less Than 50 Volts. AC circuits of less than 50 volts shall be grounded under any of the following conditions:

(1) Where supplied by transformers if the transformer supply system exceeds 150 volts to ground.

(2) Where supplied by transformers if the transformer supply system is ungrounded.

(3) Where installed as overhead conductors outside of buildings.

(b) Alternating-Current Systems of 50 Volts to 1000 Volts. AC systems of 50 volts to 1000 volts supplying premises wiring and premises wiring systems shall be grounded under any of the following conditions:

(1) Where the system can be so grounded that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts.

(2) Where the system is nominally rated 480Y/277-volt, 3-phase, 4-wire in which the neutral is used as a circuit conductor.

(3) Where the system is nominally rated 240/120-volt, 3-phase, 4-wire in which the midpoint of one phase is used as a circuit conductor.

(4) Where a service conductor is uninsulated in accordance with Section 230-4.

Exception No. 1: Electric systems used exclusively to supply industrial electric furnaces for melting, refining, tempering, and the like.

Exception No. 2: Separately derived systems used exclusively for rectifiers supplying only adjustable speed industrial drives.

Exception No. 3: Separately derived systems supplied by transformers that have a primary voltage rating less than 1000 volts provided that all of the following conditions are met:

a. The system is used exclusively for control circuits.

b. The conditions of maintenance and supervision assure that only qualified persons will service the installation.

c. Continuity of control power is required.

d. Ground detectors are installed on the control system.

Exception No. 4: Isolated systems as permitted in Article 517.

The proper use of suitable ground detectors on ungrounded systems can provide additional protection.

(c) Alternating-Current Systems of 1 kV and Over. AC systems of 1 kV and over supplying portable equipment shall be grounded. Where supplying other than portable equipment, such systems shall be permitted to be grounded. Where such systems are grounded, they shall comply with the applicable provisions of this article.

(d) Separately Derived Systems. A premises wiring system whose power is derived from generator, transformer, or converter windings and has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system, if required to be grounded as in (a) or (b) above, shall be grounded as specified in Section 250-26.

250-6. Portable and Vehicle Mounted Generators.

(a) Portable Generators. Under the following conditions the frame of a portable generator shall not be required to be grounded and shall be permitted to serve as the grounding electrode for a system supplied by the generator:

(1) The generator supplies only equipment mounted on the generator and/or cord- and plug-connected equipment through receptacles mounted on the generator, and

(2) The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame.

(b) Vehicle Mounted Generators. Under the following conditions the frame of a vehicle shall be permitted to serve as the grounding electrode for a system supplied by a generator located on the vehicle:

(1) The frame of the generator is bonded to the vehicle frame, and

(2) The generator supplies only equipment located on the vehicle and/or cord- and plug-connected equipment through receptacles mounted on the vehicle or on the generator, and

(3) The noncurrent-carrying metal parts of equipment and the equipment grounding conductor terminals of the receptacles are bonded to the generator frame, and

(4) The system complies with all other provisions of this article.

(c) Neutral Conductor Bonding. A neutral conductor shall be bonded to the generator frame when the generator is a component of a separately derived system. The bonding of any conductor other than a neutral within the generator to its frame shall not be required.

For grounding of portable generators supplying fixed wiring systems, see Section 250-5(d).

250-7. Circuits Not to Be Grounded. The following circuits shall not be grounded:

(a) Circuits for electric cranes operating over combustible fibers in Class III locations, as provided in Section 503-13.

(b) Circuits as provided in Article 517.

C. Location of System Grounding Connections

250-21. Objectionable Current over Grounding Conductors.

(a) Arrangement to Prevent Objectionable Current. The grounding of electric systems, circuit conductors, lightning arresters, and conductive noncurrent-carrying materials and equipment shall be installed and arranged in a manner that will prevent an objectionable flow of current over the grounding conductors or grounding paths.

(b) Alterations to Stop Objectionable Current. If the use of multiple grounding connections results in an objectionable flow of current, one or more of the following alterations shall be made:

(1) Discontinue one or more such grounding connections.

(2) Change the locations of the grounding connections.

(3) Interrupt the continuity of the conductor or conductive path interconnecting the grounding connections.

(4) Take other suitable remedial action satisfactory to the authority having jurisdiction.

(c) Temporary Currents Not Classified as Objectionable Currents. Temporary currents resulting from accidental conditions, such as ground-fault currents, that occur only while the grounding conductors are performing their intended protective functions shall not be classified as objectionable current for the purposes specified in (a) and (b) above.

250-22. Point of Connection for Direct-Current Systems. DC systems to be grounded shall have the grounding connection made at one or more supply stations. A grounding connection shall not be made at individual services nor at any point on premises wiring.

250-23. Grounding Connections for Alternating-Current Systems.

(a) An AC system that is grounded on the premises shall have a grounding electrode conductor connected to a grounding electrode at each service. Such supply systems that originate outside the building shall have at least one additional grounding connection made to a grounding electrode on the secondary side of the transformer supplying the system, either at the transformer or elsewhere. The grounding electrode conductor shall be connected to the AC system on the supply side of the service disconnecting means at an accessible point on the load side of the service drop or service lateral, preferably within the enclosure for the service disconnecting means. Grounding connections shall not be made on the load side of the service disconnecting means.

See definition of Service Drop and Service Lateral; also Section 230-21.

Exception No. 1: A grounding conductor shall be connected to each separately derived system as provided in Section 250-26.

Exception No. 2: A grounding conductor connection shall be made at each separate building where required by Section 250-24.

Exception No. 3: For ranges, counter-mounted cooking units, wall-mounted ovens, clothes dryers and meter enclosures as permitted by Section 250-61.

Exception No. 4: For services that are dual fed (double ended) in a common enclosure or grouped together in separate enclosures and employing a secondary tie, a single grounding electrode connection to the tie point of the grounded circuit conductors from each power source shall be permitted.

(b) Grounded Conductor Brought to Service Equipment. Where an AC system operating at 1000 volts or less is grounded at any point, the grounded conductor shall be run to each service. This conductor shall be routed with the phase conductors and shall not be smaller than the required grounding electrode conductor specified in Table 250-94 and, in addition, for service phase conductors larger than 1100 MCM, the grounded conductor shall not be smaller than 12½ percent of the area of the largest phase conductor.

Exception: The grounded conductor shall not be required to be larger than the largest ungrounded service conductor.

250-24. Two or More Buildings Supplied from Single Service Equipment.

(a) Grounded Systems: Where two or more buildings are supplied by a grounded system from a single service equipment, each building shall have a grounding electrode connected to the AC system grounded circuit conductor on the supply side of the building disconnecting means.

(b) Ungrounded Systems: Where two or more buildings are supplied by an ungrounded system from a single service equipment, each building shall have a grounding electrode connected to the metal enclosure of the building disconnecting means.

Exception for (a) and (b) above: A grounding electrode at a separate building shall not be required where the conditions of either a. or b. below are met:

a. Only one branch circuit is supplied and there is no equipment in the building that requires grounding.

b. No livestock is housed in the building, an equipment grounding conductor is run with the circuit conductors for grounding any noncurrent-carrying equipment, interior metal piping systems or building metal frames and the equipment grounding conductor is bonded to grounding electrodes described in Sections 250-81 and 250-83 which exist at the building.

250-25. Conductor to Be Grounded — Alternating-Current Systems. For AC premises wiring systems, the conductor to be grounded shall be as specified in (a) through (e) below.

(a) Single-phase, 2-wire: the identified conductor.

(b) Single-phase, 3-wire: the identified neutral conductor.

(c) Multiphase systems having one wire common to all phases: the identified common conductor.

(d) Multiphase systems having one phase grounded: the identified conductor.

(e) Multiphase systems in which one phase is used as in (b) above: the identified neutral conductor.

See Article 200 for means of identification.

250-26. Grounding Separately Derived Alternating-Current Systems. A separately derived AC system that is required to be grounded by Section 250-5 shall be grounded as specified in (a) through (d) below.

(a) A bonding jumper, sized in accordance with Section 250-79(c) for the derived phase conductors, shall be used to connect the equipment grounding conductors of the derived system to the grounded circuit conductor. Except as permitted by Exception No. 4 of Section 250-23(a), this connection shall be made at the source of the separately derived system and ahead of any system disconnecting means or overcurrent device.

(b) A grounding electrode conductor, sized in accordance with Section 250-94 for the derived phase conductors, shall be used to connect the grounded conductor of the derived system to the grounding electrode as

specified in (c) below. Except as permitted by Exception No. 4 of Section 250-23(a), this connection shall be made at the source of the separately derived system and ahead of any system disconnecting means or overcurrent device.

(c) The grounding electrode shall be as near as practicable to and preferably in the same area as the grounding conductor connection to the system. The grounding electrode shall be: (1) The nearest available effectively grounded structural metal member of the structure; or (2) The nearest available effectively grounded metal water pipe; or (3) Other electrodes as specified in Sections 250-81 and 250-83 where electrodes specified by (1) or (2) above are not available.

(d) In all other respects, grounding methods shall comply with requirements prescribed in other parts of this Code.

D. Enclosure Grounding

250-32. Service Raceways and Enclosures. Metal enclosures for service conductors and equipment shall be grounded.

250-33. Other Conductor Enclosures. Metal enclosures for other than service conductors shall be grounded.

Exception No. 1: Metal enclosures for conductors added to existing installations of open wire, knob-and-tube wiring, and nonmetallic-sheathed cable, if in runs of less than 25 feet, if free from probable contact with ground, grounded metal, metal lath, or other conductive material, and if guarded against contact by persons shall not be required to be grounded.

Exception No. 2: Metal enclosures used to protect cable assemblies from physical damage shall not be required to be grounded.

E. Equipment Grounding

250-42. Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed). Exposed noncurrent-carrying metal parts of fixed equipment likely to become energized shall be grounded under any of the conditions in (a) through (f) below.

(a) Where within 8 feet vertically or 5 feet horizontally of ground or grounded metal objects and subject to contact by persons.

(b) Where located in a wet or damp location and not isolated.

(c) Where in electrical contact with metal.

(d) Where in a hazardous location as covered by Articles 500 through 517.

(e) Where supplied by a metal-clad, metal-sheathed, or metal-raceway wiring method, except as permitted by Section 250-33 for short sections of raceway.

(f) Where equipment operates with any terminal at over 150 volts to ground.

Exception No. 1: Enclosures for switches or circuit breakers used for other than service equipment and accessible to qualified persons only.

Exception No. 2: Metal frames of electrically heated devices, exempted by special permission, in which case the frames shall be permanently and effectively insulated from ground.

Exception No. 3: Distribution apparatus, such as transformer and capacitor cases, mounted on wooden poles, at a height exceeding 8 feet above ground or grade level.

250-43. Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Specific. Exposed, noncurrent-carrying metal parts of the kinds of equipment described in (a) through (j) below, regardless of voltage, shall be grounded.

(a) Switchboard frames and structures supporting switching equipment.

Exception: Frames of DC, single-polarity switchboards where effectively insulated.

(b) Generator and motor frames in an electrically operated organ.

Exception: Where the generator is effectively insulated from ground and from the motor driving it.

(c) Motor frames, as provided by Section 430-142.

(d) Enclosures for motor controllers.

Exception: Lined covers of snap switches.

(e) Electric equipment for elevators and cranes.

(f) Electric equipment in garages, theaters, and motion picture studios.

Exception: Pendant lampholders supplied by circuits not over 150 volts to ground.

(g) Electric signs and associated equipment.

Exception: Where insulated from ground and from other conductive objects and accessible only to authorized persons.

(h) Motion picture projection equipment.

(i) Equipment supplied by Class 1, Class 2, and Class 3 remote-control and signaling circuits where required to be grounded by Part B of this article.

(j) Lighting fixtures as provided in Part E of Article 410.

250-44. Nonelectric Equipment. The metal parts of nonelectric equipment described in (a) through (e) below shall be grounded.

(a) Frames and tracks of electrically operated cranes.

(b) Frames of nonelectrically driven elevator cars to which electric conductors are attached.

(c) Hand-operated metal shifting ropes or cables of electric elevators.

(d) Metal partitions, grill work, and similar metal enclosures around equipment of over 750 volts between conductors except substations or vaults under the sole control of the supply company.

(e) Mobile homes and recreational vehicles as required in Articles 550 and 551.

Where extensive metal in or on buildings may become energized and is subject to personal contact, adequate bonding and grounding will provide additional safety.

250-45. Equipment Connected by Cord and Plug. Under any of the conditions described in (a) through (d) below, exposed noncurrent-carrying metal parts of cord- and plug-connected equipment likely to become energized, shall be grounded.

(a) In hazardous locations (see Articles 500 through 517).

(b) Where operated at over 150 volts to ground.

Exception No. 1: Motors, where guarded.

Exception No. 2: Metal frames of electrically heated appliances exempted by Section 422-16.

(c) In residential occupancies: (1) refrigerators, freezers, and air conditioners; (2) clothes-washing, clothes-drying, dish-washing machines, sump pumps, and electrical aquarium equipment; (3) hand-held motor operated tools; (4) motor operated appliances of the following types: hedge clippers, lawn mowers, snow blowers and wet scrubbers; (5) portable handlamps.

Exception: Listed tools and listed appliances protected by a system of double insulation, or its equivalent, shall not be required to be grounded. Where such a system is employed, the equipment shall be distinctively marked.

(d) In other than residential occupancies: (1) refrigerators, freezers, and air conditioners; (2) clothes-washing, clothes-drying, dish-washing machines, sump pumps and electrical aquarium equipment; (3) hand-held motor operated tools; (4) motor operated appliances of the following types: hedge clippers, lawn mowers, snow blowers and wet scrubbers; (5) cord- and plug-connected appliances used in damp or wet locations or by persons standing on the ground or on metal floors or working inside of metal tanks or boilers; (6) tools likely to be used in wet and conductive locations; and (7) portable handlamps.

Exception No. 1: Tools likely to be used in wet and conductive locations shall not be required to be grounded where supplied through an isolating transformer with an ungrounded secondary of not over 50 volts.

Exception No. 2: Listed portable tools and listed appliances protected by an approved system of double insulation, or its equivalent, shall not be required to be grounded. Where such a system is employed, the equipment shall be distinctively marked.

With reference to (c) and (d), portable tools or appliances not provided with special insulating or grounding protection are not intended to be used in damp, wet, or conductive locations.

250-46. Spacing from Lightning Rods. Metal raceways, enclosures, frames, and other noncurrent-carrying metal parts of electric equipment shall be kept at least 6 feet away from lightning rod conductors, or they shall be bonded to the lightning rod conductors.

See Sections 250-86 and 800-31(b)(5). For further information see the Lightning Protection Code NFPA 78-1977 (ANSI) which contains detailed information on grounding lightning protection systems.

F. Methods of Grounding

250-50. Equipment Grounding Conductor Connections. Equipment grounding conductor connections at the source of separately derived systems shall be made in accordance with Section 250-26(a). Equipment grounding conductor connections at service equipment shall be made on the supply side of the service disconnecting means and shall be made as indicated in (a) or (b) below.

(a) For Grounded System. The connection shall be made by bonding the equipment grounding conductor to the grounded circuit conductor and the grounding electrode conductor.

(b) For Ungrounded System. The connection shall be made by bonding the equipment grounding conductor to the grounding electrode conductor.

Exception for (a) and (b) above: For branch-circuit extensions only in existing installations that do not have an equipment grounding conductor in the branch circuit, the grounding conductor of a grounding-type receptacle outlet shall be permitted to be grounded to a grounded cold water pipe near the equipment.

250-51. Effective Grounding Path. The path to ground from circuits, equipment, and conductor enclosures shall:

(a) Be permanent and continuous.

(b) Have capacity to conduct safely any fault current likely to be imposed on it.

(c) Have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices in the circuit.

250-53. Grounding Path to Grounding Electrode.

(a) Grounding Electrode Conductor. A grounding electrode conductor shall be used to connect the equipment grounding conductors, the service-equipment enclosures and, where the system is grounded, the grounded conductor to the grounding electrode.

(b) Main Bonding Jumper. For a grounded system, an unspliced main bonding jumper shall be used to connect the equipment grounding conductor and the service-equipment enclosure to the grounded conductor of the system within the service equipment or within the service conductor enclosure. A main bonding jumper shall be a wire, bus, screw, or similar suitable conductor.

250-54. Common Grounding Electrode. Where an AC system is connected to a grounding electrode in or at a building as specified in Sections 250-23 and 250-24, the same electrode shall be used to ground conductor enclosures and equipment in or on that building.

Two or more electrodes that are effectively bonded together shall be considered as a single electrode in this sense.

250-55. Underground Service Cable. Where served from a continuous underground metal-sheathed cable system, the sheath or armor of underground service cable metallically connected to the underground system, or underground service conduit containing a metal-sheathed cable bonded to the underground system, shall not be required to be grounded at the building and shall be permitted to be insulated from the interior conduit or piping.

250-56. Short Sections of Raceway. Isolated sections of metal raceway or cable armor, where required to be grounded, shall be grounded in accordance with Section 250-57.

250-57. Equipment Fastened in Place or Connected by Permanent Wiring Methods (Fixed) — Grounding. Noncurrent-carrying metal parts of equipment, where required to be grounded, shall be grounded by one of the methods indicated in (a), (b), or (c) below.

(a) By any of the equipment grounding conductors permitted by Section 250-91(b).

installed in accordance with (a) above in regard to restrictions for aluminum and also in regard to protection from physical damage.

Exception: Sizes smaller than No. 6 shall not be required to be enclosed in a raceway or armor where run in the hollow spaces of a wall or partition or where otherwise installed so as not to be subject to physical damage.

250-93. Size of Direct-Current System Grounding Conductor. The size of the grounding conductor for a DC system shall be as specified in (a) through (c) below.

(a) Where the DC system consists of a 3-wire balancer set or a balancer winding with overcurrent protection as provided in Section 445-4(d), the grounding conductor shall not be smaller than the neutral conductor.

(b) Where the DC system is other than as in (a) above, the grounding conductor shall not be smaller than the largest conductor supplied by the system.

(c) In no case shall the grounding conductor be smaller than No. 8.

250-94. Size of Alternating-Current Grounding Electrode Conductor. The size of the grounding electrode conductor of a grounded or ungrounded AC system shall not be less than given in Table 250-94.

Exception No. 1: Grounded Systems. Where connected to made electrodes (as in Section 250-83), that portion of the grounding electrode conductor which is the sole connection between the grounding electrode and the grounded system conductor shall not be required to be larger than No. 6 copper wire or its equivalent in ampacity.

Exception No. 2: Ungrounded Systems. Where connected to made electrodes (as in Section 250-83), that portion of the grounding electrode conductor which is the sole connection between the grounding electrode and the service equipment shall not be required to be larger than No. 6 copper wire or its equivalent in ampacity.

250-95. Size of Equipment Grounding Conductors. The size of copper, aluminum, or copper-clad aluminum equipment grounding conductors shall not be less than given in Table 250-95.

Where conductors are run in parallel in multiple raceways, as permitted in Section 310-4, the equipment grounding conductor, where used, shall be run in parallel. Each parallel equipment grounding conductor shall be sized on the basis of the ampere rating of the overcurrent device protecting the circuit conductors in the raceway in accordance with Table 250-95.

When conductors are adjusted in size to compensate for voltage drop, grounding conductors, where required, shall be adjusted proportionately in size.

Exception No. 1: An equipment grounding conductor not smaller than No. 18 copper and not smaller than the circuit conductors if an integral part of a listed flexible cord assembly shall be permitted for grounding cord-connected equipment where the equipment is protected by overcurrent devices not exceeding 20-ampere rating.

Exception No. 2: The equipment grounding conductor shall not be required to be larger than the circuit conductors supplying the equipment.

Exception No. 3: Where a raceway or a cable armor or sheath is used as the equipment grounding conductor, as provided in Sections 250-57(a) and 250-91(b).

Table 250-94

Grounding Electrode Conductor for AC Systems

Size of Largest Service-Entrance Conductor or Equivalent for Parallel Conductors		Size of Grounding Electrode Conductor	
Copper	Aluminum or Copper-Clad Aluminum	Copper	*Aluminum or Copper-Clad Aluminum
2 or smaller	0 or smaller	8	6
1 or 0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250 MCM	4	2
Over 3/0 thru 350 MCM	Over 250 MCM thru 500 MCM	2	0
Over 350 MCM thru 600 MCM	Over 500 MCM thru 900 MCM	0	3/0
Over 600 MCM thru 1100 MCM	Over 900 MCM thru 1750 MCM	2/0	4/0
Over 1100 MCM	Over 1750 MCM	3/0	250 MCM

Where there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

* See installation restrictions in Section 250-92(a).

See Section 250-23(b).

250-97. Outline Lighting. Isolated noncurrent-carrying metal parts of outline lighting systems shall be permitted to be bonded together by a No. 14 conductor protected from physical damage, where a conductor complying with Section 250-95 is used to ground the group.

250-98. Grounding Conductor in Common Raceway. A grounding conductor shall be permitted in the same raceway or enclosure with other conductors of the system to which it is connected.

250-99. Grounding Conductor Continuity.

(a) Separable Connections. Separable connections such as those provided in draw-out equipment or attachment plugs and mating connectors and receptacles shall provide for first-make, last-break of the equipment grounding conductor.

Exception: Interlocked equipment, plugs, receptacles and connectors which preclude energization without grounding continuity.

(b) Switches. No automatic cutout or switch shall be placed in the grounding conductor of a premises wiring system.

Exception: Where the opening of the cutout or switch disconnects all sources of energy.

K. Grounding Conductor Connections

250-111. To Raceway or Cable Armor. The point of connection of the grounding conductor to interior metal raceways, cable armor, and the like shall be as near as practicable to the source of supply and shall be so cho-

proved for the purpose. Fittings shall effectively close any openings in the connection.

See Section 300-22(b) and (c).

349-20. Bends.

(a) Where the flexible metallic tubing shall be infrequently flexed in service after installation, the radii of bends measured to the inside of the bend shall not be less than specified in Table 349-20(b).

(b) Where the flexible metallic tubing is bent for installation purposes and is not flexed or bent as required by use after installation, the radii of bends measured to the inside of the bend shall not be less than specified in Table 349-20(c).

Table 349-20(b). Minimum Radii for Flexing Use

Trade Size	Minimum Radii
⅜ inch	10 inches
½ inch	12½ inches
¾ inch	17½ inches

Table 349-20(c). Minimum Radii for Fixed Bends

Trade Size	Minimum Radii
⅜ inch	3½ inches
½ inch	4 inches
¾ inch	5 inches

ARTICLE 350 – FLEXIBLE METAL CONDUIT

350-1. Other Articles. Installations of flexible metal conduit shall comply with the applicable provisions of Articles 300, 333, and 346.

350-2. Use. Flexible metal conduit shall not be used: (1) in wet locations, unless conductors are of the lead-covered type or of other type approved for the specific conditions; (2) in hoistways, other than provided in Section 620-21; (3) in storage-battery rooms; (4) in any hazardous location other than permitted in Section 501-4(b); (5) where rubber-covered conductors are exposed to oil, gasoline, or other materials having a deteriorating effect on rubber; nor (6) underground or embedded in poured concrete or aggregate.

350-3. Minimum Size. Flexible metal conduit less than ½-inch electrical trade size shall not be used.

Exception No. 1: For underplaster extensions as permitted in Section 344-2.

Exception No. 2: For enclosing the leads of motors as permitted in Section 430-145(b).

Exception No. 3: Flexible metal conduit of ⅜-inch nominal trade size shall be permitted in lengths not in excess of 72 inches as a part of an approved assembly or for lighting fixtures.

Table 350-3. Maximum Number of Insulated Conductors in ⅜-In. Flexible Metal Conduit.*

Col. A = With fitting inside conduit.
Col. B = With fitting outside conduit.

Size AWG	Types RFH-2, SF-2		Types TF, T, XHHW, AF, TW, RUH, RUW		Types TFN, THHN, THWN		Types FEP, FEPB, PF, PGF	
	A	B	A	B	A	B	A	B
18	..	3	3	7	4	8	5	8
16	..	2	2	4	3	7	4	8
14	..	..	..	4	3	7	3	7
12	..	..	..	3	..	4	..	4
10	..	..	..	..	..	2	..	3

* In addition, one uninsulated grounding conductor of the same AWG size shall be permitted.

350-4. Supports. Flexible metal conduit shall be secured by an approved means at intervals not exceeding 4½ feet and within 12 inches on each side of every outlet box or fitting.

Exception No. 1: Where flexible metal conduit is fished.

Exception No. 2: Lengths of not more than 3 feet at terminals where flexibility is necessary.

Exception No. 3: Lengths of not more than 6 feet from a fixture terminal connection for tap connections to lighting fixtures as required in Section 410-67(c).

350-5. Grounding. Flexible metal conduit shall be permitted as a grounding means where both the conduit and the fittings are approved for the purpose. Where an equipment bonding jumper is required around flexible metal conduit, it shall be installed in accordance with Section 250-79.

Exception: Flexible metal conduit shall be permitted as a grounding means if the total length in any ground return path is 6 feet or less, the conduit is terminated in fittings approved for the purpose, and the circuit conductors contained therein are protected by overcurrent devices rated at 20 amperes or less.

350-6. Bends in Concealed Work. A run of conduit for concealed raceway, between outlet and outlet, fitting and fitting, or outlet and fitting, shall not contain more than the equivalent of four quarter bends (360 degrees total), including those bends located immediately at the outlet or fitting.

Angle connectors shall not be used for concealed raceway installations.

ARTICLE 351 – LIQUIDTIGHT FLEXIBLE METAL CONDUIT

351-1. Scope. This article covers use and installation requirements for liquidtight flexible metal conduit.

351-2. Definition. Liquidtight flexible metal conduit is a raceway of circular cross section having an outer liquidtight, nonmetallic, sunlight-resistant jacket over an inner flexible metal core with associated couplings, connectors, and fittings and approved for the installation of electric conductors.

351-3. Other Articles. Installations of liquidtight flexible metal conduit shall comply with the applicable provisions of Articles 300 and with the specific Sections of Articles 350, 501, 502, and 503 referenced below.

351-4. Use.

(a) The use of liquidtight flexible metal conduit shall be permitted for both exposed and concealed work:

(1) Where conditions of installation, operation, or maintenance require flexibility or protection from liquids, vapors, or solids.

(2) As permitted by Sections 501-4(b), 502-4, and 503-3, and in other hazardous locations where specifically approved.

(b) Liquidtight flexible metal conduit shall not be used:

(1) Where subject to physical damage.

(2) Where any combination of ambient and/or conductor temperature will produce an operating temperature in excess of that for which the material is approved.

351-5. Size.

(a) Minimum. Liquidtight flexible metal conduit smaller than ½-inch electrical trade size shall not be used.

Exception: ⅜-inch size shall be permitted as covered in Section 350-3.

(b) Maximum. The maximum size of liquidtight flexible metal conduit shall be the 4-inch trade size.

351-6. Number of Conductors.

(a) The number of conductors permitted in a single conduit, ½- through 4-inch trade sizes, shall not exceed the percentage of fill specified in Table 1, Chapter 9.

(b) The number of conductors permitted in ⅜-inch liquidtight flexible metal conduit shall not exceed that permitted in Table 350-3.

351-7. Fittings. Liquidtight flexible metal conduit shall be used only with terminal fittings approved for the purpose.

351-8. Supports. Where liquidtight flexible metal conduit is installed as a fixed raceway, it shall be secured at intervals not exceeding 4½ feet and within 12 inches on each side of every outlet box or fitting.

Exception No. 1: Where liquidtight flexible metal conduit is fished.

Exception No. 2: Lengths of not more than 3 feet at terminals where flexibility is desired.

351-9. Grounding. Liquidtight flexible metal conduit shall be permitted as a grounding conductor where both the conduit and the fittings are approved for the purpose. Where an equipment bonding jumper is required around liquidtight flexible metal conduit, it shall be installed in accordance with Section 250-79.

Exception: Liquidtight flexible metal conduit shall be permitted as a grounding means in the 1¼-inch and smaller trade sizes if the total length in any ground return path is 6 feet or less and the conduit is terminated in fittings approved for the purpose.

351-10. Bends In Concealed Work. A run of conduit for concealed raceway, between outlet and outlet, fitting and fitting, or outlet and fitting, shall not contain more than the equivalent of four quarter bends (360 degrees total), including those bends located immediately at the outlet or fitting.

Angle connectors shall not be used for concealed raceway installations.

ARTICLE 352 – SURFACE RACEWAYS

A. Metal Surface Raceways

352-1. Use. The use of surface raceways shall be permitted in dry locations. They shall not be used: (1) where subject to severe physical damage unless approved for the purpose; (2) where 300 volts or more between conductors unless the metal has a thickness of not less than .040 inch; (3) where subject to corrosive vapors; (4) in hoistways; (5) in any hazardous location except Class I, Division 2 locations as permitted in the Exception to 501-4(b); nor (6) concealed except as follows:

Exception No. 1: Metal surface raceways approved for the purpose shall be permitted for underplaster extensions.

Exception No. 2: As permitted in Section 645-2(c)(2).

See definition of "Exposed – (As applied to wiring methods)" in Article 100.

352-2. Other Articles. Metal surface raceways shall comply with the applicable provisions of Article 300.

352-3. Size of Conductors. No conductor larger than that for which the raceway is designed shall be installed in metal surface raceway.

352-4. Number of Conductors in Raceways. The number of conductors installed in any raceway shall be no greater than the number for which the raceway is designed.

The derating factors in Note 8 to Tables 310-16 through 310-19 shall not apply to conductors installed in surface raceways when all of the following conditions are met: (1) The cross-sectional area of the raceway exceeds 4 square inches; (2) The current-carrying conductors do not exceed 30 in number; (3) The sum of the cross-sectional area of all contained conductors does not exceed 20 percent of the interior cross-sectional area of the surface raceway.

ARTICLE 370 – OUTLET, SWITCH AND JUNCTION BOXES, AND FITTINGS

A. Scope and General

370-1. Scope. This article covers the installation and use of boxes containing outlets, receptacles, switches or devices; junction or pull boxes and conduit bodies as required by Section 300-15. Fittings referred to in Section 300-15 used as outlet, junction or pull boxes shall conform with the provisions of this article depending on their use.

Installations in hazardous locations shall conform to Articles 500 through 517.

For systems over 600 volts, nominal, see Part D of this article.

370-2. Round Boxes. Round boxes shall not be used where conduits or connectors requiring the use of locknuts or bushings are to be connected to the side of the box.

370-3. Nonmetallic Boxes. Nonmetallic boxes not over 100 cubic inches shall be permitted only with open wiring on insulators, concealed knob-and-tube wiring, nonmetallic-sheathed cable, and with rigid nonmetallic conduit.

Nonmetallic boxes over 100 cubic inches manufactured with bonding means between all raceway and cable entries shall be permitted to be used with metal raceways and metal-sheathed cable.

370-4. Metal Boxes. Where used with knob-and-tube wiring or nonmetallic-sheathed cable, and mounted on or in contact with metal or metal lath ceilings, walls, or metallic surfaces, metal boxes shall be grounded.

B. Installation

370-5. Damp or Wet Locations. In damp or wet locations, boxes and fittings shall be so placed or equipped as to prevent moisture from entering or accumulating within the box or fitting. Boxes and fittings installed in wet locations shall be approved for the purpose.

For boxes in floors, see Section 370-17(b).
For protection against corrosion, see Section 300-6.

370-6. Number of Conductors in Switch, Outlet, Receptacle, Device, and Junction Boxes. Boxes shall be of sufficient size to provide free space for all conductors enclosed in the box.

The provisions of this section shall not apply to terminal housings supplied with motors. (See Section 430-12.)

Boxes and conduit bodies containing conductors, size No. 4 or larger, shall also comply with the provisions of Section 370-18.

(a) Standard Boxes. The maximum number of conductors, not counting fixture wires permitted in standard boxes, shall be as is listed in Table 370-6(a). See Section 370-18 where boxes or conduit bodies are used as junction or pull boxes.

Table 370-6(a). Metal Boxes

Box Dimension, Inches Trade Size or Type	Min. Cu. In. Cap.	Maximum Number of Conductors				
		No.14	No.12	No.10	No.8	No.6
4 x 1¼ Round or Octagonal	12.5	6	5	5	4	0
4 x 1½ Round or Octagonal	15.5	7	6	6	5	0
4 x 2⅛ Round or Octagonal	21.5	10	9	8	7	0
4 x 1¼ Square	18.0	9	8	7	6	0
4 x 1½ Square	21.0	10	9	8	7	0
4 x 2⅛ Square	30.3	15	13	12	10	6*
4 11/16 x 1¼ Square	25.5	12	11	10	8	0
4 11/16 x 1½ Square	29.5	14	13	11	9	0
4 11/16 x 2⅛ Square	42.0	21	18	16	14	6
3 x 2 x 1½ Device	7.5	3	3	3	2	0
3 x 2 x 2 Device	10.0	5	4	4	3	0
3 x 2 x 2¼ Device	10.5	5	4	4	3	0
3 x 2 x 2½ Device	12.5	6	5	5	4	0
3 x 2 x 2¾ Device	14.0	7	6	5	4	0
3 x 2 x 3½ Device	18.0	9	8	7	6	0
4 x 2⅛ x 1½ Device	10.3	5	4	4	3	0
4 x 2⅛ x 1⅞ Device	13.0	6	5	5	4	0
4 x 2⅛ x 2⅛ Device	14.5	7	6	5	4	0
3¾ x 2 x 2½ Masonry Box/Gang	14.0	7	6	5	4	0
3¾ x 2 x 3½ Masonry Box/Gang	21.0	10	9	8	7	0
FS—Minimum Internal Depth 1¾ Single Cover/Gang	13.5	6	6	5	4	0
FD—Minimum Internal Depth 2⅜ Single Cover/Gang	18.0	9	8	7	6	3
FS—Minimum Internal Depth 1¾ Multiple Cover/Gang	18.0	9	8	7	6	0
FD—Minimum Internal Depth 2⅜ Multiple Cover/Gang	24.0	12	10	9	8	4

* Not to be used as a pull box. For termination only.

(1) Table 370-6(a) shall apply where no fittings or devices, such as fixture studs, cable clamps, hickeys, switches, or receptacles, are contained in the box and where no grounding conductors are part of the wiring within the box. Where one or more fixture studs, cable clamps, or hickeys are contained in the box, the number of conductors shall be one less than shown in the tables; an additional deduction of one conductor shall be made for each strap containing one or more devices; and a further deduction of one conductor shall be made for one or more grounding conductors entering the box. A conductor running through the box shall be counted as one conductor, and each conductor originating outside of the box and terminating inside the box is counted as one conductor. Conductors, no part of which leaves the box, shall not be counted. The volume of a wiring enclosure (box) shall be the total volume of the assembled sections, and where used, the space provided by plaster rings, domed covers, extension rings, etc. that are marked with their volume in cubic inches.

(2) For combinations of conductor sizes shown in Table 370-6(a), the volume per conductor listed in Table 370-6(b) shall apply. The maximum number and size of conductors listed in Table 370-6(a) shall not be exceeded.

(b) Other Boxes. Boxes 100 cubic inches or less other than those described in Table 370-6(a), conduit bodies having provision for more than two conduit entries and nonmetallic boxes shall be durably and legibly

marked by the manufacturer with their cubic inch capacity and the maximum number of conductors permitted shall be computed using the volume per conductor listed in Table 370-6(b) and the deductions provided for in Section 370-6(a)(1). Boxes described in Table 370-6(a) that have a larger cubic inch capacity than is designated in the table shall be permitted to have their cubic inch capacity marked as required by this section and the maximum number of conductors permitted shall be computed using the volume per conductor listed in Table 370-6(b).

Table 370-6(b). Volume Required Per Conductor

Size of Conductor	Free Space Within Box for Each Conductor
No. 14	2. cubic inches
No. 12	2.25 cubic inches
No. 10	2.5 cubic inches
No. 8	3. cubic inches
No. 6	5. cubic inches

Where No. 6 conductors are installed the minimum wire bending space required in Table 373-6(a) shall be provided.

(c) Conduit Bodies. Conduit bodies enclosing No. 6 conductors or smaller shall have a cross-sectional area not less than twice the cross-sectional area of the largest conduit to which it is attached. The maximum number of conductors permitted shall be the maximum number permitted by Table I, Chapter 9, for the conduit to which it is attached.

Conduit bodies having provisions for less than three conduit entries shall not contain splices, taps or devices unless they comply with the provisions of 370-6(b) and are supported in a rigid and secure manner.

370-7. Conductors Entering Boxes or Fittings. Conductors entering boxes or fittings shall be protected from abrasion, and shall comply with (a) through (d) below.

(a) Openings to Be Closed. Openings through which conductors enter shall be adequately closed.

(b) Metal Boxes and Fittings. Where metal outlet boxes or fittings are installed with open wiring or concealed knob-and-tube wiring, conductors shall enter through insulating bushings or, in dry places, through flexible tubing extending from the last insulating support and firmly secured to the box or fitting. Where raceway or cable is installed with metal outlet boxes or fittings, the raceway or cable shall be secured to such boxes and fittings.

(c) Nonmetallic Boxes. Where nonmetallic boxes are used with open wiring or concealed knob-and-tube wiring, the conductors shall enter the box through individual holes. Where flexible tubing is used to encase the conductors, the tubing shall extend from the last insulating support to no less than ¼ inch inside the box. Where nonmetallic-sheathed cable is used, the cable assembly, including the sheath, shall extend into the box no less than ¼ inch through a nonmetallic-sheathed cable knockout opening. Where nonmetallic-sheathed cable is used with single gang boxes and where the cable is fastened within 8 inches of the box measured along the sheath and where the sheath extends into the box no less than ¼ inch, securing the cable to the box shall not be required. In all other instances individual conductors and cables shall be secured to nonmetallic boxes.

(d) Conductors No. 4 AWG or Larger. Installation shall comply with Section 373-6(c).

370-8. Unused Openings. Unused openings in boxes and fittings shall be effectively closed to afford protection substantially equivalent to that of the wall of the box or fitting. Metal plugs or plates used with nonmetallic boxes or fittings shall be recessed at least ¼ inch from the outer surface.

370-9. Boxes Enclosing Flush Devices. Boxes used to enclose flush devices shall be of such design that the devices will be completely enclosed on back and sides, and that substantial support for the devices will be provided. Screws for supporting the box shall not be used in attachment of the device contained therein.

370-10. In Wall or Ceiling. In walls or ceilings of concrete, tile, or other noncombustible material, boxes and fittings shall be so installed that the front edge of the box or fitting will not set back of the finished surface more than ¼ inch. In walls and ceilings constructed of wood or other combustible material, outlet boxes and fittings shall be flush with the finished surface or project therefrom.

370-11. Repairing Plaster. Plaster surfaces that are broken or incomplete shall be repaired so there will be no gaps or open spaces at the edge of the box or fitting.

Exception: On walls or ceilings of concrete, tile, or other noncombustible material.

370-12. Exposed Surface Extensions. In making an exposed surface extension from an existing outlet of concealed wiring, a box or an extension ring shall be mounted over the original box and electrically and mechanically secured to it.

370-13. Supports. Boxes shall be securely and rigidly fastened to the surface upon which they are mounted, or securely and rigidly embedded in concrete or masonry. Where nails are used as a mounting means and pass through the interior of the box, they shall not be permitted to be more than ¼ inch from the back of the box. Boxes shall be supported from a structural member of the building either directly or by using a substantial and approved metal or wooden brace, or shall be supported as is otherwise provided in this section. If of wood, the brace shall not be less than nominal one-inch thickness. If of metal it shall be corrosion-resistant and shall not be less than No. 24 MSG.

Where mounted in new walls in which no structural members are provided or in existing walls in previously occupied buildings, boxes not over 100 cubic inches in size, specifically approved for the purpose, shall be affixed with approved anchors or clamps so as to provide a rigid and secure installation.

Threaded boxes or fittings not over 100 cubic inches in size that do not contain devices or support fixtures shall be considered adequately supported if two or more conduits are threaded into the box wrenchtight and are supported within 3 feet of the box on two or more sides as is required by this section.

Threaded boxes or fittings not over 100 cubic inches in size shall be considered to be adequately supported if two or more conduits are threaded

secured to the box proper by screws or bolts instead of hinges. Boxes having covers of this form shall be used only for enclosing joints in conductors or to facilitate the drawing in of wires and cables. They shall not be used to enclose switches, cutouts, or other control devices.

370-21. Covers. Metal covers shall be of a thickness not less than that specified for the walls of the box or fitting of the same material and with which they are designed to be used, or shall be lined with firmly attached insulating material not less than 1/32 inch in thickness. Covers of porcelain or other approved insulating material shall be permitted if of such form and thickness as to afford the required protection and strength.

370-22. Bushings. Covers of outlet boxes and outlet fittings having holes through which flexible cord pendants may pass, shall be provided with approved bushings or shall have smooth, well-rounded surfaces, upon which the cord may bear. Where conductors other than flexible cord may pass through a metal cover, a separate hole equipped with a bushing of suitable insulating material shall be provided for each conductor.

370-23. Nonmetallic Boxes. Provisions for supports or other mounting means for nonmetallic boxes shall be outside of the box, or the box shall be so constructed as to prevent contact between the conductors in the box and the supporting screws.

370-24. Marking. All boxes and conduit bodies, covers, extension rings, plaster rings, and the like shall be durably and legibly marked with the manufacturer's name or trademark.

D. Pull and Junction Boxes for Use on Systems Over 600-Volts, Nominal

370-50. General. In addition to the generally applicable provisions of Article 370, the rules in Sections 370-51 and 370-52 shall apply.

370-51. Size of Pull and Junction Boxes. Pull and junction boxes shall provide adequate space and dimensions for the installation of conductors in accordance with the following:

(a) For Straight Pulls. The length of the box shall be not less than 48 times the outside diameter, over sheath, of the largest conductor or cable entering the box.

(b) For Angle or U Pulls. The distance between each cable or conductor entry inside the box and the opposite wall of the box shall not be less than 36 times the outside diameter, over sheath, of the largest cable or conductor. This distance shall be increased for additional entries by the amount of the sum of the outside diameters, over sheath, of all other cables or conductor entries through the same wall of the box.

The distance between a cable or conductor entry and its exit from the box shall be not less than 36 times the outside diameter, over sheath, of that cable or conductor.

Exception No. 1: Where a conductor or cable entry is in the wall of a box opposite to a removable cover and where the distance from that wall to the cover is in conformance with the provisions of Section 300-34.

Exception No. 2: Terminal housings supplied with motors which shall comply with the provisions of Section 430-12.

(c) One or more sides of any pull box shall be removable.

370-52. Construction and Installation Requirements.

(a) Boxes shall be made of material inherently resistant to corrosion or shall be suitably protected, both internally and externally, by enameling, galvanizing, plating or other means.

(b) Suitable bushing, shields, or fittings having smooth rounded edges shall be provided where conductors or cables pass through partitions and at other locations where necessary.

(c) Boxes shall provide a complete enclosure for the contained conductors or cables.

(d) Boxes shall be so installed that the wiring is accessible without removing any part of the building. Working space shall be provided in accordance with Section 110-34.

(e) Boxes shall be closed by suitable covers securely fastened in place. Underground box covers that weigh over one hundred pounds shall be considered as meeting this requirement. Covers for boxes shall be permanently marked "HIGH VOLTAGE." The marking shall be on the outside of the box cover and shall be readily visible. Letters shall be block type at least ½ inch in height.

(f) Boxes and their covers shall be capable of withstanding the handling to which they may be subjected.

ARTICLE 373 – CABINETS AND CUTOUT BOXES

373-1. Scope. This article covers the installation of cabinets and cutout boxes. Installations in hazardous locations shall comply with Articles 500 through 517.

A. Installation

373-2. Damp or Wet Locations. In damp or wet locations, cabinets and cutout boxes of the surface type shall be so placed or equipped as to prevent moisture or water from entering and accumulating within the cabinet or cutout box, and shall be mounted so there is at least ¼-inch air space between the enclosure and the wall or other supporting surface. Cabinets or cutout boxes installed in wet locations shall be weatherproof.

For protection against corrosion, see Section 300-6.

373-3. Position in Wall. In walls of concrete, tile, or other noncombustible material, cabinets shall be so installed that the front edge of the cabinet will not set back of the finished surface more than ¼ inch. In walls constructed of wood or other combustible material, cabinets shall be flush with the finished surface or project therefrom.

373-4. Unused Openings. Unused openings in cabinet or cutout boxes shall be effectively closed to afford protection substantially equivalent to that of the wall of the cabinet or cutout box. Where metal plugs or plates are used with nonmetallic cabinets or cutout boxes, they shall be recessed at least ¼ inch from the outer surface.

373-5. Conductors Entering Cabinets or Cutout Boxes. Conductors entering cabinets or cutout boxes shall be protected from abrasion and shall comply with (a) through (c) below.

(a) Openings to Be Closed. Openings through which conductors enter shall be adequately closed.

(b) Metal Cabinets and Cutout Boxes. Where metal cabinets or cutout boxes are installed with open wiring or concealed knob-and-tube wiring, conductors shall enter through insulating bushings or, in dry places, through flexible tubing extending from the last insulating support and firmly secured to the cabinet or cutout box.

(c) Cables. Where cable is used, each cable shall be secured to the cabinet or cutout box.

373-6. Deflection of Conductors. Conductors at terminals or conductors entering or leaving cabinets or cutout boxes and the like shall comply with (a) through (c) below.

(a) Width of Wiring Gutters. Conductors shall not be deflected within a cabinet or cutout box unless a gutter having a width in accordance with Table 373-6(a) is provided. Conductors in parallel in accordance with Section 310-4 shall be judged on the basis of the number of conductors in parallel.

Table 373-6(a). Minimum Wire Bending Space at Terminals and Minimum Width of Wiring Gutters in Inches

AWG or Circular-Mil Size of Wire	Wires per Terminal 1	2	3	4	5
14-10	Not Specified	—	—	—	—
8-6	1½	—	—	—	—
4-3	2	—	—	—	—
2	2½	—	—	—	—
1	3	—	—	—	—
0-00	3½	5	7	—	—
000-0000	4	6	8	—	—
250 MCM	4½	6	8	10	—
300-350 MCM	5	8	10	12	—
400-500 MCM	6	8	10	12	14
600-700 MCM	8	10	12	14	16
750-900 MCM	8	12	14	16	18
1,000-1,250 MCM	10	—	—	—	—
1,500-2,000 MCM	12	—	—	—	—

Bending space at terminals shall be measured in a straight line from the end of the lug or wire connector (in the direction that the wire leaves the terminal) to the wall or barrier.

(b) Wire Bending Space at Terminals. Conductors shall not be deflected at a terminal unless bending space in accordance with Table 373-6(a) is provided.

(c) Insulated Bushings. Where ungrounded conductors of No. 4 or larger enter a raceway in a cabinet, pull box, junction box, or auxiliary gutter, the conductors shall be protected by a substantial bushing providing a smoothly rounded insulating surface, unless the conductors are separated from the raceway fitting by substantial insulating material securely fastened in place. Where conduit bushings are constructed wholly of insulating material, a locknut shall be installed both inside and outside the enclosure to which the conduit is attached. The insulating bushing or insulating material shall have a temperature rating not less than the insulation temperature rating of the installed conductors.

373-7. Space in Enclosures. Cabinets and cutout boxes shall have sufficient space to accommodate all conductors installed in them without crowding.

373-8. Enclosures for Switches or Overcurrent Devices. Enclosures for switches or overcurrent devices shall not be used as junction boxes, auxiliary gutters, or raceways for conductors feeding through or tapping off to other switches or overcurrent devices.

Exception: Where adequate space is provided so that the conductors do not fill the wiring space at any cross section to more than 40 percent of the cross-sectional area of the space, and so that the conductors, splices, and taps do not fill the wiring space at any cross section to more than 75 percent of the cross-sectional area of the space.

373-9. Side or Back Wiring Spaces or Gutters. Cabinets and cutout boxes shall be provided with back wiring spaces, gutters, or wiring compartments as required by Sections 373-11(c) and (d).

B. Construction Specifications

373-10. Material. Cabinets and cutout boxes shall comply with (a) through (c) below.

(a) Metal Cabinets and Cutout Boxes. Metal cabinets and cutout boxes shall be protected both inside and outside against corrosion and shall be approved for the purpose.

For protection against corrosion, see Section 300-6.

(b) Strength. The design and construction of cabinets and cutout boxes shall be such as to secure ample strength and rigidity. If constructed of sheet steel, the metal shall not be less than No. 16 MSG.

(c) Nonmetallic Cabinets. Nonmetallic cabinets shall be submitted for approval prior to installation.

373-11. Spacing. The spacing within cabinets and cutout boxes shall comply with (a) through (d) below.

(a) General. Spacing within cabinets and cutout boxes shall be sufficient to provide ample room for the distribution of wires and cables placed in them, and for a separation between metal parts of devices and apparatus mounted within them as follows:

(1) Base. Other than at points of support, there shall be an air space of at least 1/16 inch between the base of the device and the wall of any metal cabinet or cutout box in which the device is mounted.

(2) Doors. There shall be an air space of at least one inch between any live metal part, including live metal parts of enclosed fuses, and the door.

Exception: Where the door is lined with an approved insulating material or is of a thickness of metal not less than No. 12 MSG, the air space shall not be less than ½ inch.

(3) Live Parts. There shall be an air space of at least ½ inch between the walls, back, gutter partition, if of metal, or door of any cabinet or cut-

shall be made tight and where the assembly is held together by rivets or bolts, these shall be spaced not more than 12 inches apart.

(c) Suitable bushings, shields, or fittings having smooth rounded edges shall be provided where conductors pass between gutters, through partitions, around bends, between gutters and cabinets or junction boxes, and at other locations where necessary to prevent abrasion of the insulation of the conductors.

(d) Where insulated conductors are deflected within an auxiliary gutter, either at the ends or where conduits, fittings, or other raceways enter or leave the gutter, or where the direction of the gutter is deflected greater than 30 degrees, dimensions corresponding to Section 373-6 shall apply.

(e) Auxiliary gutters intended for outdoor use shall be of approved raintight construction.

ARTICLE 380 – SWITCHES

A. Installation

380-1. Scope. The provisions of this article shall apply to all switches, switching devices, and circuit breakers where used as switches.

380-2. Switch Connections.

(a) Three-Way and Four-Way Switches. Three-way and four-way switches shall be so wired that all switching is done only in the ungrounded circuit conductor. Where in metal enclosures, wiring between switches and outlets shall be run with both polarities in the same enclosure.

(b) Grounded Conductors. Switches or circuit breakers shall not disconnect the grounded conductor of a circuit.

Exception No. 1: Where the switch or circuit breaker simultaneously disconnects all conductors of the circuit.

Exception No. 2: Where the switch or circuit breaker is so arranged that the grounded conductor cannot be disconnected until all the ungrounded conductors of the circuit have been disconnected.

380-3. Enclosure. Switches and circuit breakers shall be of the externally operable type enclosed in boxes or cabinets approved for the purpose. The minimum wire bending space at terminals and minimum gutter space provided in switch enclosures shall be as required in Section 373-6.

Exception: Pendant- and surface-type snap switches and knife switches mounted on an open-face switchboard or panelboard.

380-4. Wet Locations. A switch or circuit breaker in a wet location or outside of a building shall be enclosed in a weatherproof enclosure or cabinet that shall comply with Section 373-2.

380-5. Time Switches, Flashers, and Similar Devices. Time switches, flashers, and similar devices need not be of the externally operable type. They shall be enclosed in metal boxes or cabinets.

Exception No. 1. Where mounted in switchboards, control panels, or enclosures and so located that any live terminals, located within 6 inches of the manually adjustable clock dial or "on-off" switch, are covered by suitable barriers.

Exception No. 2. Where enclosed in approved individual housings with no live parts exposed to the operator.

380-6. Position of Knife Switches.

(a) Single-Throw Knife Switches. Single-throw knife switches shall be so placed that gravity will not tend to close them. Single-throw knife switches, approved for use in the inverted position, shall be provided with a locking device that will ensure that the blades remain in the open position when so set.

(b) Double-Throw Knife Switches. Double-throw knife switches shall be permitted to be mounted so that the throw will be either vertical or horizontal. Where the throw is vertical, a locking device shall be provided, the blades remaining in the open position when so set.

380-7. Connection of Knife Switches. Single-throw knife switches shall be so connected that the blades are dead when the switch is in the open position.

380-8. Accessibility and Grouping.

(a) All switches and circuit breakers used as switches shall be located that they may be operated from a readily accessible place. They shall be so installed that the center of the grip of the operating handle of the switch or circuit breaker, when in its highest position, will not be more than 6½ feet above the floor or working platform.

Exception No. 1: On busway installations, fused switches and circuit breakers shall be permitted to be located at the same level as the busway. Suitable means shall be provided to operate the handle of the device from the floor.

Exception No. 2: Switches installed adjacent to motors, appliances or other equipment which they supply shall be permitted to be located higher than specified in the foregoing and to be accessible by portable means.

Exception No. 3: Hookstick operable isolating switches shall be permitted at heights of more than 6 feet, 6 inches.

(b) Snap switches shall not be grouped or ganged in outlet boxes unless they can be so arranged that the voltage between adjacent switches does not exceed 300, or unless they are installed in boxes equipped with permanently installed barriers between adjacent switches.

380-9. Faceplates for Flush-Mounted Snap Switches. Flush snap switches, that are mounted in ungrounded metal boxes and located within reach of conducting floors or other conducting surfaces, shall be provided with faceplates of nonconducting, noncombustible material. Metal faceplates shall be of ferrous metal not less than 0.030 inch in thickness or of nonferrous metal not less than 0.040 inch in thickness. Faceplates of insulating material shall be noncombustible and not less than 0.10 inch in thickness but they shall be permitted to be less than 0.10 inch in thickness if formed or reinforced to provide adequate mechanical strength. Faceplates shall be installed so as to completely cover the wall opening and seat against the wall surface.

380-10. Mounting of Snap Switches.

(a) Surface-Type. Snap switches used with open wiring on insulators shall be mounted on insulating material that will separate the conductors at least ½ inch from the surface wired over.

(b) Box Mounted. Flush-type snap switches mounted in boxes that are set back of the wall surface as permitted in Section 370-10 shall be installed so that the extension plaster ears are seated against the surface of the wall. Flush-type snap switches mounted in boxes that are flush with the wall surface or project therefrom shall be so installed that the mounting yoke or strap of the switch is seated against the box.

380-11. Circuit Breakers as Switches. A hand-operable circuit breaker equipped with a lever or handle, or a power-operated circuit breaker capable of being opened by hand in the event of a power failure, shall be permitted to serve as a switch if it has the required number of poles.

380-12. Grounding of Enclosures. Enclosures for switches or circuit breakers on circuits of over 150 volts to ground shall be grounded as specified in Article 250. Where nonmetallic enclosures are used with metal-sheathed cables or metallic conduits, provision shall be made for grounding continuity.

380-13. Knife Switches.

(a) Knife switches rated at over 1200 amperes at 250 volts or less, and at over 600 amperes at 251 to 600 volts, shall be used only as isolating switches and shall not be opened under load.

(b) To interrupt currents over 1200 amperes at 250 volts or less, or over 600 amperes at 251 to 600 volts, a circuit breaker or a switch of special design approved for such purpose shall be used.

(c) Knife switches of ratings less than specified in (a) and (b) above shall be considered general-use switches.

See definition of general-use switch in Article 100.

(d) Motor-circuit switches shall be permitted to be of the knife-switch type.

See definition of a motor-circuit switch in Article 100.

380-14. Rating and Use of Snap Switches. Snap switches shall be used within their ratings and as follows:

(a) AC General-Use Snap Switch. A form of general-use snap switch suitable only for use on alternating-current circuits for controlling the following:

(1) Resistive and inductive loads, including electric-discharge lamps, not exceeding the ampere rating of the switch at the voltage involved.

(2) Tungsten-filament lamp loads not exceeding the ampere rating of the switch at 120 volts.

(3) Motor loads not exceeding 80 percent of the ampere rating of the switch at its rated voltage.

(4) Snap switches rated 20 amperes or less directly connected to aluminum conductors shall be approved for the purpose and marked CO/ALR.

(b) AC-DC General-Use Snap Switch. A form of general-use snap switch suitable for use on either AC or DC circuits for controlling the following:

(1) Resistive loads not exceeding the ampere rating of the switch at the voltage applied.

(2) Inductive loads not exceeding 50 percent of the ampere rating of the switch at the applied voltage. Switches rated in horsepower are suitable for controlling motor loads within their rating at voltage applied.

(3) Tungsten-filament lamp loads not exceeding the ampere rating of the switch at the applied voltage if "T" rated.

For switches on signs and outline lighting, see Section 600-2.

For switches controlling motors, see Sections 430-83, 430-109, and 430-110.

B. Construction Specifications

380-15. Marking. Switches shall be marked with the current and voltage and, if horsepower rated, the maximum rating for which they are designed.

380-16. 600-Volt Knife Switches. Auxiliary contacts of a renewable or quick-break type or the equivalent, shall be provided on all 600-volt knife switches designed for use in breaking currents over 200 amperes.

380-17. Fused Switches. A fused switch shall not have fuses in parallel.

ARTICLE 384 – SWITCHBOARDS AND PANELBOARDS

384-1. Scope. This article covers (1) all switchboards, panelboards, and distribution boards installed for the control of light and power circuits, and (2) battery-charging panels supplied from light or power circuits.

Exception: Switchboards or portions thereof used exclusively to control signaling circuits operated by batteries.

384-2. Other Articles. Switches, circuit breakers, and overcurrent devices used on switchboards, panelboards, and distribution boards, and their enclosures, shall comply with the requirements of Articles 240, 250, 370, 380, and other articles that apply. Switchboards and panelboards in hazardous locations shall comply with the requirements of Articles 500 through 517.

384-3. Support and Arrangement of Busbars and Conductors.

(a) Conductors and busbars on a switchboard, panelboard, or control board shall be so located as to be free from physical damage and shall be held firmly in place. Other than the required interconnections and control wiring, only those conductors that are intended for termination in a vertical section of a switchboard shall be located in that section. Barriers shall be placed in all service switchboards that will isolate the service busbars and terminals from the remainder of the switchboard.

(b) The arrangement of busbars and conductors shall be such as to avoid overheating due to inductive effects.

(c) Each switchboard, switchboard section, or panelboard, if used as service equipment, shall be provided with a main bonding jumper sized in accordance with Section 250-79(c) or the equivalent placed within the service disconnect section for connecting the grounded service conductor on its supply side to the switchboard or panelboard frame. All sections of a switchboard shall be bonded together using an equipment grounding conductor sized in accordance with Table 250-95.

(d) Load terminals in switchboards and panelboards shall be so located that it will be unnecessary to reach across or beyond an ungrounded line bus in order to make load connections.

(e) On a switchboard or a panelboard supplied from a 4-wire delta-connected system, where the mid-point of one phase is grounded, that phase busbar or conductor having the higher voltage to ground shall be marked.

(f) The phase arrangement on three phase buses shall be A, B, C from front to back, top to bottom, or left to right, as viewed from the front of the switchboard or panelboard. The B phase shall be that phase having the higher voltage to ground. Other busbar arrangements shall be permitted for additions to existing installations and shall be marked.

(g) The minimum wire bending space at terminals and minimum gutter space provided in panelboards and switchboards shall be as required in Section 373-6.

A. Switchboards

384-4. Location of Switchboards. Switchboards that have any exposed live parts shall be located in permanently dry locations and then only where under competent supervision and accessible only to qualified persons. Switchboards shall be so located that the probability of damage from equipment or processes is reduced to a minimum.

384-5. Wet Locations. Where a switchboard is in a wet location or outside of a building, it shall be enclosed in a weatherproof enclosure or cabinet installed to comply with Section 373-2.

384-6. Location Relative to Easily Ignitible Material. Switchboards shall be so placed as to reduce to a minimum the probability of communicating fire to adjacent combustible materials.

384-7. Clearance From Ceiling. A space of 3 feet or more shall be provided between the top of any switchboard and any nonfireproof ceiling.

Exception No. 1: Where a fireproof shield is provided between the switchboard and the ceiling.

Exception No. 2: Totally enclosed switchboards.

384-8. Clearances Around Switchboards. Clearances around switchboards shall comply with the provisions of Section 110-16.

384-9. Conductor Covering. Insulated conductors where closely grouped, as on the rear of switchboards, shall each have a flame-retardant outer covering. The conductor covering shall be stripped back to avoid contact with the terminals. Insulated conductors used for instrument and control wiring on the rear of switchboards shall be flame-retardant, either inherently or by means of an outer covering, such as one of the following types: RH, RHH, RHW, V, ALS, AVA, AVB, SIS, T, TA, TBS, TW, THHN, THWN, THW, MI, XHHW, or other types approved for the purpose.

384-10. Clearance for Conductors Entering Bus Enclosures. Where conduits or other raceways enter a switchboard, floor standing panelboard, or similar enclosure at the bottom, sufficient space shall be provided to permit installation of conductors in the enclosure. The wiring space shall not be less than shown in the following table where the conduit or raceways enter or leave the enclosure below the busbars, their supports, or other obstructions. The conduit or raceways, including their end fittings shall not rise more than 3 inches above the bottom of the enclosure.

Conductor	Minimum Spacing Between Bottom of Enclosure and Busbars, their Supports, or other Obstructions (Inches)
Insulated busbars, their supports, or other obstructions	8
Noninsulated busbars	10

384-11. Grounding Switchboard Frames. Switchboard frames and structures supporting switching equipment shall be grounded.

Exception: Frames of direct-current single-polarity switchboards shall not be required to be grounded if effectively insulated.

384-12. Grounding of Instruments, Relays, Meters, and Instrument Transformers on Switchboards. Instruments, relays, meters, and instrument transformers located on switchboards shall be grounded as specified in Sections 250-121 through 250-125.

B. Panelboards

384-13. General. All panelboards shall have a rating not less than the minimum feeder capacity required for the load computed in accordance with Article 220. Panelboards shall be durably marked by the manufacturer with the voltage and the current rating and the number of phases for which they are designed and with the manufacturer's name or trademark in such a manner as to be visible after installation, without disturbing the interior parts or wiring.

384-14. Lighting and Appliance Branch-Circuit Panelboard. For the purposes of this article, a lighting and appliance branch-circuit panelboard is one having more than 10 percent of its overcurrent devices rated 30 amperes or less, for which neutral connections are provided.

384-15. Number of Overcurrent Devices on One Panelboard. Not more than 42 overcurrent devices (other than those provided for in the mains) of a lighting and appliance branch-circuit panelboard shall be installed in any one cabinet or cutout box.

A lighting and appliance branch-circuit panelboard shall be provided with physical means to prevent the installation of more overcurrent devices than that number for which the panelboard was designed, rated, and approved.

For the purposes of this article, a 2-pole circuit breaker shall be considered two overcurrent devices; a 3-pole breaker shall be considered three overcurrent devices.

384-16. Overcurrent Protection.

(a) Each lighting and appliance branch-circuit panelboard shall be indi-

vidually protected on the supply side by not more than two main circuit breakers or two sets of fuses having a combined rating not greater than that of the panelboard.

Exception No. 1: Individual protection for a lighting and appliance panelboard shall not be required if the panelboard feeder has overcurrent protection not greater than that of the panelboard.

Exception No. 2: Individual protection for lighting and appliance branch-circuit panelboards is not required where such panelboards are used as service equipment in supplying an individual residential occupancy.

(b) Panelboards equipped with snap switches rated at 30 amperes or less, shall have overcurrent protection not in excess of 200 amperes.

(c) The total load on any overcurrent device located in a panelboard shall not exceed 80 percent of its rating where in normal operation the load will continue for 3 hours or more.

Exception: Where the assembly including the overcurrent device is approved for continuous duty at 100 percent of its rating.

(d) Where a panelboard is supplied through a transformer, the overcurrent protection required in (a) and (b) above shall be located on the secondary side of the transformer.

Exception: A panelboard supplied by the secondary side of a single-phase transformer having a two-wire (single-voltage) secondary shall be considered as protected by overcurrent protection provided on the primary (supply) side of the transformer, provided this protection is in accordance with Section 450-3(b)(1) and does not exceed the value determined by multiplying the panelboard rating by the secondary-to-primary voltage ratio.

(e) A three phase disconnect or overcurrent device shall not be connected to the bus of any panelboard that has less than three phase buses.

This is intended to prohibit the use of "delta breakers" in panelboards.

384-17. Panelboards in Damp or Wet Locations. Panelboards in damp or wet locations shall be installed to comply with Section 373-2.

384-18. Enclosure. Panelboards shall be mounted in cabinets, cutout boxes, or enclosures approved for the purpose and shall be dead front.

Exception: Panelboards other than of the dead front externally operable type shall be permitted where accessible only to qualified persons.

384-19. Relative Arrangement of Switches and Fuses. In panelboards, fuses of any type shall be installed on the load side of any switches.

Exception: As provided in Section 230-94 for use as service equipment.

C. Construction Specifications

384-20. Panels. The panels of switchboards shall be made of moisture-resistant, noncombustible material.

384-21. Busbars. Bare busbars shall be permitted if they are rigidly mounted.

384-22. Protection of Instrument Circuits. Instruments, pilot lights, potential transformers, and other switchboard devices with potential coils shall be supplied by a circuit that is protected by standard overcurrent devices rated 15 amperes or less.

Exception No. 1: Where the operation of the overcurrent device might introduce a hazard in the operation of devices.

Exception No. 2: For ratings of 2 amperes or less, special types of enclosed fuses shall be permitted.

384-23. Component Parts. Switches, fuses, and fuseholders used on panelboards shall comply with the applicable requirements of Articles 240 and 380.

384-24. Knife Switches. Exposed blades of knife switches shall be dead when open.

384-26. Minimum Spacings. The distance between bare metal parts, busbars, etc., shall not be less than specified in Table 384-26.

Exception No. 1: At switches or circuit breakers.

Exception No. 2: Inherent spacings in listed components.

Where close proximity does not cause excessive heating, parts of the same polarity at switches, enclosed fuses, etc. shall be permitted to be placed as close together as convenience in handling will allow.

Table 384-26. Minimum Spacings Between Bare Metal Parts

	Opposite Polarity Where Mounted on the Same Surface	Opposite Polarity Where Held Free In Air	*Live Parts to Ground
Not over 125 volts	¾ inch	½ inch	½ inch
Not over 250 volts	1¼ inch	¾ inch	½ inch
Not over 600 volts	2 inches	1 inch	1 inch

* For spacing between live parts and doors of cabinets, see Section 373-11(a) (1), (2), and (3).

384-27. Grounding of Panelboards. Panelboard cabinets shall be grounded in the manner specified in Article 250 or Section 384-3(c). An approved terminal bar for equipment grounding conductors shall be provided and secured inside of the cabinet for the attachment of all the feeder and branch-circuit equipment grounding conductors, where the panelboard is used with nonmetallic raceway or cable, or where separate grounding conductors are provided. The terminal bar shall be bonded to the cabinet or panelboard frame and shall not be connected to the neutral bar in other than service equipment.

Exception: When an isolated ground conductor is provided as in Section 250-74, Exception No. 4, the insulated ground conductor which is run with the circuit conductors shall be permitted to pass through the panelboard without being connected to the panelboard grounding terminal bar.

appliance are required, data for selection of these devices shall be marked on the appliance. The minimum marking shall be that specified in Sections 430-7 and 440-3.

(b) A household-type appliance with surface heating elements having a maximum demand of more than 60 amperes computed in accordance with Table 220-19 shall have its power supply subdivided into two or more circuits, each of which is provided with overcurrent protection rated at not over 50 amperes.

(c) Infrared lamp commercial and industrial heating appliances shall have overcurrent protection not exceeding 50 amperes.

(d) Open-coil or exposed sheathed-coil types of surface heating elements in commercial-type heating appliances shall be protected by overcurrent protective devices rated at not over 50 amperes.

(e) If the branch circuit supplies a single nonmotor-operated appliance, rated at 16.7 amperes or more, the overcurrent device rating shall not exceed 150 percent of the appliance rating.

(f) Electric heating appliances employing resistance-type heating elements rated more than 48 amperes shall have the heating elements subdivided. Each subdivided load shall not exceed 48 amperes and shall be protected at not more than 60 amperes.

These supplementary overcurrent protective devices shall be: (1) factory installed within or on the heater enclosure or provided as a separate assembly by the heater manufacturer; and (2) accessible, but need not be readily accessible; and (3) suitable for branch-circuit protection.

The main conductors supplying these overcurrent protective devices shall be considered branch-circuit conductors.

Exception No. 1: Household-type appliances with surface heating elements as covered in Section 422-27(b) and commercial-type heating appliances as covered in Section 422-27(d).

Exception No. 2: Commercial kitchen and cooking appliances using sheathed-type heating elements not covered in Section 422-27(d) shall be permitted to be subdivided into circuits not exceeding 120 amperes and protected at not more than 150 amperes where one of the following is met:

a. Elements are integral with and enclosed within a cooking surface;

b. Elements are completely contained within an enclosure approved for the purpose; or

c. Elements are contained within an ASME rated and stamped vessel.

Exception No. 3: Water heaters and steam boilers employing resistance-type immersion electric heating elements contained in an ASME rated and stamped vessel shall be permitted to be subdivided into circuits not exceeding 120 amperes and protected at not more than 150 amperes.

E. Marking of Appliances

422-30. Nameplate.

(a) Each electric appliance shall be provided with a nameplate, giving the identifying name and the rating in volts and amperes, or in volts and watts. If the appliance is to be used on a specific frequency or frequencies, it shall be so marked.

Whe tor overload protection external to the appliance is required, the app e shall be so marked.

See Section 422-27(a) Exception for overcurrent protection requirements.

(b) Marking shall be located so as to be visible or easily accessible after installation.

422-31. Marking of Heating Elements. All heating elements that are rated over one ampere, replaceable in the field, and a part of an appliance shall be legibly marked with the ratings in volts and amperes, or in volts and watts, or with the manufacturer's part number.

422-32. Appliances Consisting of Motors and Other Loads. Appliances shall be marked in accordance with (a) or (b) below.

(a) In addition to the marking required in Section 422-30, the marking on an appliance consisting of a motor with other load(s) or motors with or without other load(s) shall specify the minimum circuit size and the maximum rating of the circuit overcurrent protective device.

Exception No. 1: Appliances factory-equipped with cords and attachment plugs, complying with Section 422-30.

Exception No. 2: An appliance where both the minimum circuit size and maximum rating of the circuit overcurrent protective device are not more than 15 amperes and complies with Section 422-30.

(b) An alternate marking method shall be permitted to specify the rating of the largest motor in volts and amperes, and the additional load(s) in volts and amperes, or volts and watts in addition to the marking required in Section 422-30.

Exception No. 1: Appliances factory-equipped with cords and attachment plugs, complying with Section 422-30.

Exception No. 2: The ampere rating of a motor ⅛ hp or less or a nonmotor load one ampere or less shall be permitted to be omitted unless such loads constitute the principal load.

ARTICLE 424 – FIXED ELECTRIC SPACE HEATING EQUIPMENT

A. General

424-1. Scope. This article covers fixed electric equipment used for space heating. Equipment shall be of a type approved for the purpose and location where installed. For the purpose of this article, heating equipment shall include heating cable, unit heaters, boilers, central systems, or other approved fixed electric space heating equipment. This article shall not apply to process heating and room air conditioning.

424-2. Other Articles. All requirements of this Code shall apply where applicable. Fixed electric space heating equipment for use in hazardous locations shall comply with Articles 500 through 517. Fixed electric space heating equipment incorporating a hermetic refrigerant motor-compressor shall also comply with Article 440.

. Branch Circuits.

Branch-Circuit Requirements. Individual branch circuits shall be

permitted to supply any size fixed electric space heating equipment.

Branch circuits supplying two or more outlets for fixed electric space heating equipment shall be rated 15, 20, or 30 amperes.

Exception: In other than residential occupancies, fixed infrared heating equipment shall be permitted to be supplied from branch circuits rated not over 50 amperes.

(b) Branch-Circuit Sizing. The size of branch-circuit conductors and overcurrent protective devices supplying fixed electric space heating equipment consisting of resistance elements with or without a motor shall be computed on the basis of 125 percent of the total load of the motors and the heaters. A contactor, thermostat, relay, or similar device, approved for continuous operation at 100 percent of its rating, shall be permitted to supply its full-rated load as provided in Section 210-22(c), Exception No. 3.

The size of the branch-circuit conductors and overcurrent protective devices supplying fixed electric space heating equipment consisting of mechanical refrigeration with or without resistance units shall be computed in accordance with Sections 440-34 and 440-35.

The provisions of this section shall not apply to conductors which form an integral part of approved fixed electric space heating equipment.

B. Installation

424-9. General. All fixed electric space heating equipment shall be installed in an approved manner.

424-10. Special Permission. Fixed electric space heating equipment and systems installed by methods other than covered by this article may be used only by special permission.

424-11. Supply Conductors. Fixed electric space heating equipment requiring supply conductors with over 60°C insulation shall be clearly and permanently marked. This marking shall be plainly visible after installation and shall be permitted to be adjacent to the field-connection box.

424-12. Locations.

(a) Fixed electric space heating equipment shall not be used where exposed to severe physical damage unless adequately protected.

(b) Heaters and related equipment installed in damp or wet locations shall be approved for such locations and shall be constructed and installed so that water cannot enter or accumulate in or on wired sections, electrical components, or duct work.

See Section 110-11 for equipment exposed to deteriorating agents.

424-13. Spacing from Combustible Materials. Fixed electric space heating equipment shall be installed to provide the required spacing between the equipment and adjacent combustible material, unless it has been found to be acceptable where installed in direct contact with combustible material.

424-14. Grounding. All exposed metal parts of fixed electric space heating equipment likely to become energized shall be grounded as required in Article 250.

C. Control and Protection of Fixed Electric Space Heating Equipment

424-19. Disconnecting Means. Means shall be provided to disconnect the heater, motor controller(s), and supplementary overcurrent protective device(s) of all fixed electric space heating equipment from all ungrounded conductors. Where heating equipment is supplied by more than one source, the disconnecting means shall be grouped and identified.

(a) Heating Equipment with Supplementary Overcurrent Protection. The disconnecting means for fixed electric space heating equipment with supplementary overcurrent protection shall be within sight from and on the supply side of the supplementary overcurrent protection device(s), and in addition shall comply with either (1) or (2) below.

(1) Heater Containing No Motor Rated Over ⅛ Horsepower. The above disconnecting means or unit switches complying with Section 424-19(b) (3) shall be permitted to serve as the required disconnecting means for both the motor controller(s) and heater under either (a) or (b) below.

a. The disconnecting means provided is also within sight from the motor controller(s) and the heater; or

b. The disconnecting means provided shall be capable of being locked in the open position.

(2) Heater Containing a Motor(s) Rated Over ⅛ Horsepower.

a. The above disconnecting means shall be permitted to serve as the required disconnecting means for both the motor controller(s) and heater if this disconnecting means is also in sight from the motor controller(s) and the heater.

b. Where the disconnecting means is not within sight from the heater a separate disconnecting means shall be installed, or the disconnecting means shall be capable of being locked in the open position, or unit switches complying with Section 424-19(b) (3) shall be permitted.

c. Where the disconnecting means is not within sight from the motor controller location a disconnecting means complying with Section 430-102 shall be provided.

d. Where the motor is not in sight from the motor controller location, Section 430-86 shall apply.

(b) Heating Equipment Without Supplementary Overcurrent Protection.

(1) Without Motor or With Motor Not Over ⅛ Horsepower. For fixed electric space heating equipment without a motor rated over ⅛ horsepower, the branch-circuit switch or circuit breaker shall be permitted to serve as the disconnecting means, where readily accessible for servicing.

(2) Over ⅛ Horsepower. For motor-driven electric space heating equipment with a motor rated over ⅛ horsepower a disconnecting means shall be located within sight from the motor controller.

Exception: As permitted by Section 424-19(a) (2).

(3) Unit Switches as Disconnecting Means. Unit switches with a marked "off" position that are part of a fixed heater and disconnect all ungrounded conductors shall be permitted as the disconnecting means required by this article where other means for disconnection are provided in the following types of occupancies.

a. Multifamily Dwellings. In multifamily dwellings, the other disconnecting means shall be within the dwelling unit or on the same floor as the dwelling units in which the fixed heater is installed, and shall also be permitted to control lamps and appliances.

b. Two-Family Dwellings. In two-family dwellings, the other dis-

connecting means shall be permitted either inside or outside of the dwelling unit in which the fixed heater is installed.

c. One-Family Dwellings. In one-family dwelling units the service disconnecting means shall be permitted to be the other disconnecting means.

d. Other Occupancies. In other occupancies, the branch-circuit switch or circuit breaker, where readily accessible for servicing of the fixed heater, shall be permitted as the other disconnecting means.

424-20. Thermostatically Controlled Switching Devices.

(a) Thermostatically controlled switching devices and combination thermostats and manually controlled switches shall be permitted to serve as both controllers and disconnecting means provided all of the following conditions are met:

(1) Provided with a marked "off" position.

(2) Directly open all ungrounded conductors when manually placed in the "off" position.

(3) Designed so that the circuit cannot be energized automatically after the device has been manually placed in the "off" position.

(4) Located as specified in Section 424-19.

(b) Thermostats that do not directly interrupt all ungrounded conductors and operate remote control circuits shall not be required to meet the requirements of (a) above. These devices shall not be permitted as the disconnecting means.

424-21. Switch and Circuit Breaker to be Indicating. Switches and circuit breakers used as disconnecting means shall be of the indicating type.

424-22. Overcurrent Protection.

(a) Branch-Circuit Devices. Electric space heating equipment, other than such motor-operated equipment as required by Articles 430 and 440 to have additional overcurrent protection, shall be considered as protected against overcurrent where supplied by one of the branch circuits in Article 210.

(b) Resistance Elements. Electric space heating equipment employing resistance-type heating elements rated more than 48 amperes shall have the heating elements subdivided. Each subdivided load shall not exceed 48 amperes and shall be protected at not more than 60 amperes.

Exception: As provided in Section 424-72(a).

(c) Overcurrent Protective Devices. The supplementary overcurrent protective devices specified in (b) above shall be: (1) factory installed within or on the heater enclosure or supplied for use with the heater as a separate assembly by the heater manufacturer; (2) accessible, but shall not be required to be readily accessible; and (3) suitable for branch-circuit protection.

See Section 240-10.

Where cartridge fuses are used to provide this overcurrent protection, a single disconnecting means shall be permitted to be used for the several subdivided loads.

See Section 240-40.

(d) Branch-Circuit Conductors. The conductors supplying the supplementary overcurrent protective devices shall be considered branch-circuit conductors.

Exception: For heaters rated 50 kW or more, the conductors supplying the supplementary overcurrent protective devices specified in (c) above shall be permitted to be sized at not less than 100 percent of the nameplate rating of the heater provided all of the following conditions are met:

a. The heater is marked with a minimum conductor size; and

b. The conductors are not smaller than the marked minimum size; and

c. A temperature-actuated device controls the cyclic operation of the equipment.

(e) Conductors for Subdivided Loads. The ampacity of field wired conductors between the heater and the supplementary overcurrent protective devices shall not be less than 100 percent of the rating or setting of the overcurrent protective device protecting the subdivided circuit(s).

Exception: For heaters rated 50 kW or more, the ampacity of field wired conductors between the heater and the supplementary overcurrent protective devices shall be permitted to be not less than 100 percent of the load of their respective subdivided circuits provided all of the following conditions are met:

a. The heater is marked with a minimum conductor size; and

b. The conductors are not smaller than the marked minimum size; and

c. A temperature-activated device controls the cyclic operation of the equipment.

D. Marking of Heating Equipment

424-28. Nameplate.

(a) Marking Required. Each unit of fixed electric space heating equipment shall be provided with a nameplate giving the identifying name and the normal rating in volts and watts, or in volts and amperes.

Electric space heating equipment intended for use on alternating current only or direct current only shall be marked to so indicate. The marking of equipment consisting of motors over ⅛ horsepower and other loads shall specify the rating of the motor in volts, amperes, and frequency, and the heating load in volts and watts, or in volts and amperes.

(b) Location. This nameplate shall be located so as to be visible or easily accessible after installation.

424-29. Marking of Heating Elements. All heating elements that are replaceable in the field and are a part of an electric heater shall be legibly marked with the ratings in volts and watts, or in volts and amperes.

E. Electric Space Heating Cables and Panels

424-34. Heating Cable and Heating Panel Construction. Heating cables and heating panels shall be furnished complete with factory-assembled nonheating leads at least 7 feet in length.

424-35. Marking of Heating Cables and Panels. Each unit shall be marked with the identifying name or identification symbol, catalog number, ratings in volts and watts, or in volts and amperes.

(a) Heating Cables. Each unit length of heating cable shall have a per-

manent legible marking on each nonheating lead located within 3 inches of the terminal end. The lead wire shall have the following color identification: 120-volt nominal, yellow; 208-volt nominal, blue; 240-volt nominal, red; and 277-volt nominal, brown.

(b) Heating Panels. Heating panels shall be permanently marked in a location that is readily visible prior to application of panel finish.

424-36. Clearances of Wiring in Ceilings. Wiring located above heated ceilings shall be spaced not less than 2 inches above the heated ceiling and shall be considered as operating at an ambient of 50°C. The ampacity of conductors shall be computed on the basis of the correction factors given in Tables 310-16 through 310-19.

Exception: Wiring above heated ceilings and located above thermal insulation having a minimum thickness of 2 inches shall not require correction for temperature.

424-37. Clearances of Branch-Circuit Wiring in Walls.

(a) Exterior Walls. Where located in exterior walls, wiring shall be located outside the thermal insulation.

(b) Interior Walls. Where heating panels are located in interior walls or partitions, any wiring behind the heating panels shall be considered as operating at an ambient of 40°C (104°F); and the ampacity of conductors shall be computed on the basis of the correction factors given in Tables 310-16 through 310-19.

424-38. Area Restrictions.

(a) Heating cables and panels shall not extend beyond the room or area in which they originate.

(b) Cables and panels shall not be installed in closets, over walls or partitions that extend to the ceiling, or over cabinets whose clearance from the ceiling is less than the minimum horizontal dimension of the cabinet to the nearest cabinet edge that is open to the room or area.

Exception: Isolated single runs of cable shall be permitted to pass over partitions where they are embedded.

(c) This provision shall not prevent the use of cable or panels in closet ceilings as low temperature heat sources to control relative humidity, provided they are used only in those portions of the ceiling that are unobstructed to the floor by shelves or other permanent fixtures.

424-39. Clearance from Other Objects and Openings. Heating elements of panels and cables shall be separated at least 8 inches from the edge of outlet boxes and junction boxes that are to be used for mounting surface lighting fixtures. A clearance of not less than two inches shall be provided from recessed fixtures and their trims, ventilating openings, and other such openings in room surfaces. Sufficient area shall be provided to assure that no heating cable or panel will be covered by any surface mounted lighting units.

424-40. Splices. Embedded cables shall be spliced only where necessary and only by approved means, and in no case shall the length of the heating cable be altered.

424-41. Installation of Heating Cables on Dry Board, in Plaster and on Concrete Ceilings.

(a) Cables shall not be installed in walls.

Exception: Isolated single runs of cable shall be permitted to run down a vertical surface to reach a dropped ceiling.

(b) Adjacent runs of cable not exceeding 2¾ watts per foot shall be installed not less than 1½ inches on centers.

(c) Heating cables shall be applied only to gypsum board, plaster lath or other fire-resistant material. With metal lath or other electrically conductive surfaces, a coat of plaster shall be applied to completely separate the metal lath or conductive surface from the cable.

See also (f) below.

(d) All heating cables, the splice between the heating cable and nonheating leads, and 3-inch minimum of the nonheating lead at the splice shall be embedded in plaster or dry board in the same manner as the heating cable.

(e) The entire ceiling surface shall have a finish of thermally noninsulating sand plaster having a nominal thickness of ½ inch, or other noninsulating material approved for the purpose and applied according to specified thickness and directions.

(f) Cables shall be secured at intervals not exceeding 16 inches by means of approved stapling, tape, plaster, nonmetallic spreaders, or other approved means. Staples or metal fasteners that straddle the cable shall not be used with metal lath or other electrically conductive surfaces.

Exception: Cables approved for the purpose shall be permitted to be secured at intervals not to exceed six feet by approved means.

(g) In dry board installations, the entire ceiling below the heating cable shall be covered with gypsum board not exceeding ½-inch thickness. The void between the upper layer of gypsum board, plaster lath, or other fire-resistant material and the surface layer of gypsum board shall be completely filled with thermally conductive nonshrinking plaster or other approved material or equivalent thermal conductivity.

(h) Cables shall be kept free from contact with metal or other electrical conductive surfaces.

(i) In dry-board applications, cable shall be installed parallel to the joist, leaving a clear space centered under the joist of 2½ inches (width) between centers of adjacent runs of cable. Crossing of joist by cable shall be kept to a minimum. Surface layer of gypsum board shall be mounted so that the nails or other fasteners do not pierce the heating cable.

Where practicable, cables shall cross joists only at the ends of a room.

424-42. Finished Ceilings. Finished ceilings shall not be covered with decorative panels or beams constructed of materials which have thermal insulating properties, such as wood, fiber, or plastic. Finished ceilings shall be permitted to be covered with paint, wallpaper, or other approved surface finishes.

424-43. Installation of Nonheating Leads of Cables and Panels.

(a) Free nonheating leads of cables and panels shall be installed in accordance with approved wiring methods from the junction box to a loca-

tion within the ceiling. Such installations shall be permitted to be single conductors in approved raceways, single or multiconductor Type UF, Type NMC, Type MI, or other approved conductors.

(b) Not less than 6 inches of free nonheating lead shall be within the junction box. The marking of the leads shall be visible in the junction box.

(c) Excess leads of heating cables shall not be cut but shall be secured to the underside of the ceiling and embedded in plaster or other approved material, leaving only a length sufficient to reach the junction box with not less than 6 inches of free lead within the box.

(d) Excess nonheating leads of heating panels shall be permitted to be cut to the required length. They shall meet the installation requirements of the wiring method employed in accordance with Section 424-43(a). Nonheating leads shall be considered to be an integral part of an approved fixed electric space heating panel and not subject to the ampacity requirements of Section 424-3(b) for branch circuits.

424-44. Installation of Panels or Cables in Concrete or Poured Masonry Floors.

(a) Panels or heating units shall not exceed 33 watts per square foot of heated area or 16½ watts per linear foot of cable.

(b) The spacing between adjacent runs of cable shall not be less than one inch on centers.

(c) Cables shall be secured in place by nonmetallic frames or spreaders or other approved means while the concrete or other finish is applied.

Cables, units, and panels shall not be installed where they bridge expansion joints unless protected from expansion and contraction.

(d) Spacings shall be maintained between the heating cable and metal embedded in the floor.

Exception: Grounded metal-clad cable shall be permitted to be in contact with metal embedded in the floor.

(e) Leads shall be protected where they leave the floor by rigid metal conduit, intermediate metal conduit, electrical metallic tubing, or by other approved means.

(f) Bushings or approved fittings shall be used where the leads emerge within the floor slab.

424-45. Inspection and Tests. Cable installations shall be made with due care to prevent damage to the cable assembly and shall be inspected and approved before cables are covered or concealed.

424-46. Panels — General. Sections 424-46 through 424-48 cover only heating panels of less than 25 watts per square foot assembled together in the field to form a heating installation in one room or area using approved methods of interconnection. Such an installation shall be connected by a recognized wiring method.

424-47. Panels to Be Complete Units. Panels shall be installed as complete units unless approved for field cutting in a recognized manner.

424-48. Installation. Panels shall be installed in an approved manner. Nails, staples, or other electrically conductive fasteners shall not be used where they penetrate current-carrying parts.

Exception: Insulated fasteners shall be permitted with systems for which they are recognized.

F. Duct Heaters

424-57. General. Part F shall apply to any heater mounted in the air stream of a forced-air system where the air moving unit is not provided as an integral part of the equipment.

424-58. Approved. Heaters installed in an air duct shall be approved for the purpose and installed in the approved manner.

424-59. Air Flow. Means shall be provided to assure uniform and adequate air flow over the face of the heater.

Heaters installed within 4 feet of a fan outlet, elbows, baffle plates, or other obstruction in duct work may require turning vanes, pressure plates, or other devices on the inlet side of the duct heater to assure an even distribution of air over the face of the heater.

424-60. Elevated Inlet Temperature. Duct heaters intended for use with elevated inlet air temperature (such as heat pumps) shall be approved for the purpose and so marked.

424-61. Installation of Duct Heaters with Heat Pumps and Air Conditioners. Heat pumps and air conditioners having duct heaters closer than 4 feet to the heat pump or air conditioner shall have both the duct heater and heat pump or air conditioner approved for such installation and so marked.

424-62. Condensation. Duct heaters used with air conditioners or other air-cooling equipment that may result in condensation of moisture shall be approved for use with air conditioners.

424-63. Fan Circuit Interlock. Means shall be provided to ensure that the fan circuit is energized when the first heater circuit is energized. However, time or temperature controlled delay in energizing the fan motor shall be permitted.

424-64. Limit Controls. Each duct heater shall be provided with an approved, integral, automatic-reset temperature-limiting control or controllers to de-energize the circuit or circuits.

In addition, an integral independent supplementary control or controllers shall be provided in each duct heater that will disconnect a sufficient number of conductors to interrupt current flow. This device shall be manually resettable or replaceable.

424-65. Location of Disconnecting Means. Duct heater controller equipment shall be accessible with the disconnecting means installed at or within sight from the controller.

Exception: As permitted by Section 424-19(a).

424-66. Installation. Duct heaters shall be installed in accordance with the manufacturer's instructions in a manner so that operation will not create a hazard to persons or property. Furthermore, duct heaters shall be located with respect to building construction and other equipment so as to permit access to the heater. Sufficient clearance shall be maintained to permit replacement of controls and heating elements and for adjusting and cleaning of controls and other parts requiring such attention. See Section 110-16.

For additional installation information, see Air Conditioning and Ven-

ARTICLE 550 – MOBILE HOMES AND MOBILE HOME PARKS

550-1. Scope.

(a) The provisions of this article cover the electrical conductors and equipment installed within or on mobile homes, the conductors that connect mobile homes to a supply of electricity, and the installation of electrical wiring, fixtures, equipment and appurtenances related to electrical installations within a mobile home park up to the mobile home service-entrance conductors or, if none, the mobile home service equipment.

Wherever the requirements of other articles of this Code and Article 550 differ, the requirements of Article 550 shall apply.

For requirements on body and frame design, construction, and the installation of plumbing and heating systems in mobile homes, refer to Standard for Mobile Homes NFPA 501B-1977 (ANSI).

(b) A mobile home not intended as a dwelling unit, as for example equipped for sleeping purposes only, contractor's on-site offices, construction job dormitories, mobile studio dressing rooms, banks, clinics, mobile stores, or intended for the display or demonstration of merchandise or machinery, shall not be required to meet the provisions of this article pertaining to the number or capacity of circuits required. It shall, however, meet all other applicable requirements of this article if provided with an electrical installation intended to be energized from a 115-volt or 115/230-volt AC power supply system.

(c) Mobile homes installed in other than mobile home parks shall comply with the provisions of this article.

(d) The provisions of this article apply to mobile homes intended for connection to a wiring system nominally rated 115/230-volts, 3-wire AC, with grounded neutral.

(e) All electrical materials, devices, appliances, fittings and other equipment shall be listed or labeled by a nationally recognized testing agency and shall be connected in an approved manner when installed.

550-2. Definitions.

Appliance, Portable: An appliance which is actually moved or can easily be moved from one place to another in normal use.

For the purpose of this article, the following major appliances other than built-in are considered portable if cord-connected: refrigerators, gas range equipment, clothes washers, dishwashers without booster heaters, or other similar appliances.

Distribution Panelboard: See definition of panelboard in Article 100.

Feeder Assembly: The overhead or under-chassis feeder conductors, including the grounding conductor, together with the necessary fittings and equipment or a power-supply cord approved for mobile home use, designed for the purpose of delivering energy from the source of electrical supply to the distribution panelboard within the mobile home.

Laundry Area: An area containing or designed to contain either a laundry tray, clothes washer, and/or a clothes dryer.

Mobile Home: A factory-assembled structure or structures equipped with the necessary service connections and made so as to be readily movable as a unit or units on its own running gear and designed to be used as a dwelling unit(s) without a permanent foundation.

The phrase "without a permanent foundation" indicates that the support system is constructed with the intent that the mobile home placed thereon will be moved from time to time at the convenience of the owner.

Mobile Home Accessory Building or Structure: Any awning, cabana, ramada, storage cabinet, carport, fence, windbreak or porch established for the use of the occupant of the mobile home upon a mobile home lot.

Mobile Home Lot: A designated portion of a mobile home park designed for the accommodation of one mobile home and its accessory buildings or structures for the exclusive use of its occupants.

Mobile Home Park: A contiguous parcel of land which is used for the accommodation of occupied mobile homes.

Mobile Home Service Equipment: The equipment containing the disconnecting means, overcurrent protective devices, and receptacles or other means for connecting a mobile home feeder assembly.

Park Electrical Wiring Systems: All of the electrical wiring, fixtures, equipment and appurtenances related to electrical installations within a mobile home park, including the mobile home service equipment.

A. Mobile Homes

550-3. Power Supply.

(a) The mobile home service equipment shall be located adjacent to the mobile home and not mounted in or on the mobile home. The power supply to the mobile home shall be a feeder assembly consisting of not more than one approved 50-ampere mobile home power-supply cord with integral molded cap, or a permanently installed circuit.

Exception: A mobile home that is factory-equipped with gas or oil-fired central heating equipment and cooking appliances shall be permitted to be provided with an approved mobile home power-supply cord rated 40 amperes.

(b) If the mobile home has a power-supply cord, it shall be permanently attached to the distribution panelboard or to a junction box permanently connected to the distribution panelboard, with the free end terminating in an attachment plug cap.

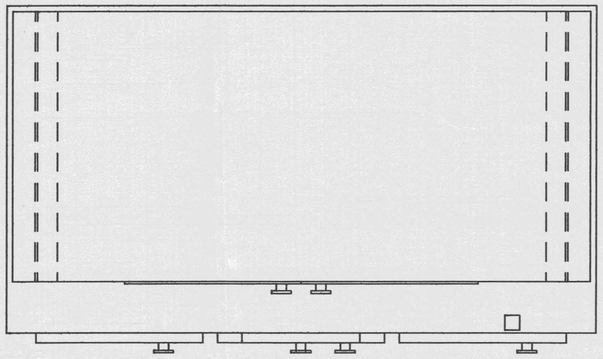
(c) Cords with adapters and pigtail ends, extension cords, and similar items shall not be attached to, or shipped with, a mobile home.

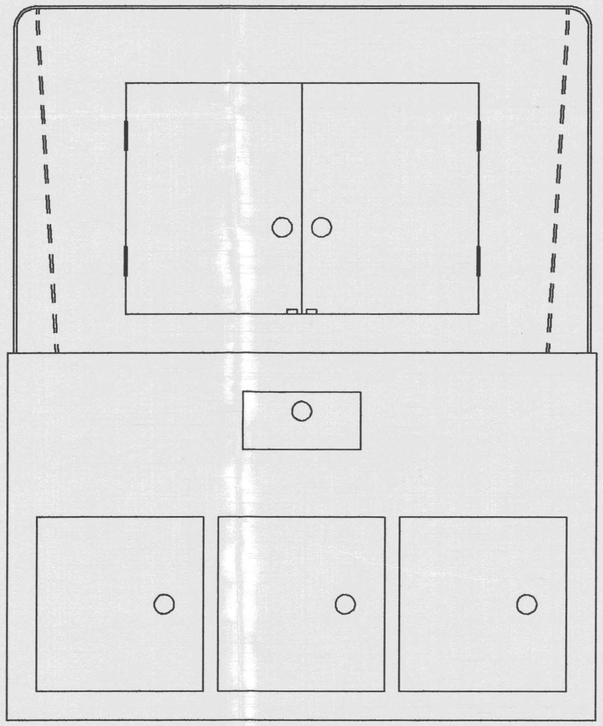
(d) A suitable clamp or the equivalent shall be provided at the distribution panelboard knockout to afford strain relief for the cord to prevent strain from being transmitted to the terminals when the power supply cord is handled in its intended manner.

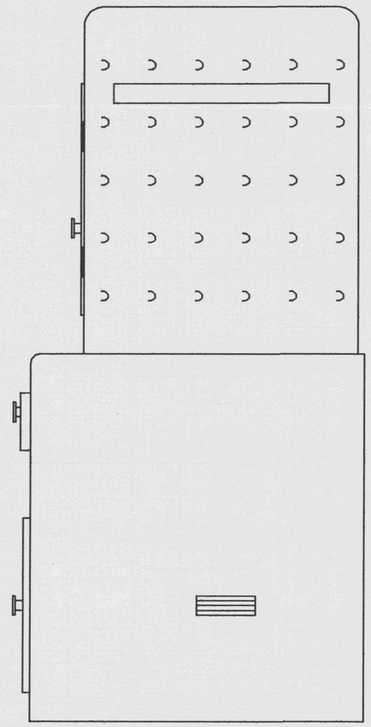
(e) The cord used shall be of an approved type with four conductors, one of which shall be identified by a continuous green color or a continuous green color with one or more yellow stripes for use as the grounding conductor.

(f) The attachment plug cap shall be a 3-pole 4-wire grounding type, rated 50 amperes, 125/250 volts with a configuration as shown in Figure 550-3(f) and intended for use with the 50-ampere, 125/250 receptacle configuration shown in Figure 550-3(f). It shall be molded of butyl rubber, neoprene, or other materials which have been found suitable for the pur-

REV. LETTER	REVISION DESCRIPTION	DATE	BY







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BABY CHAMBER

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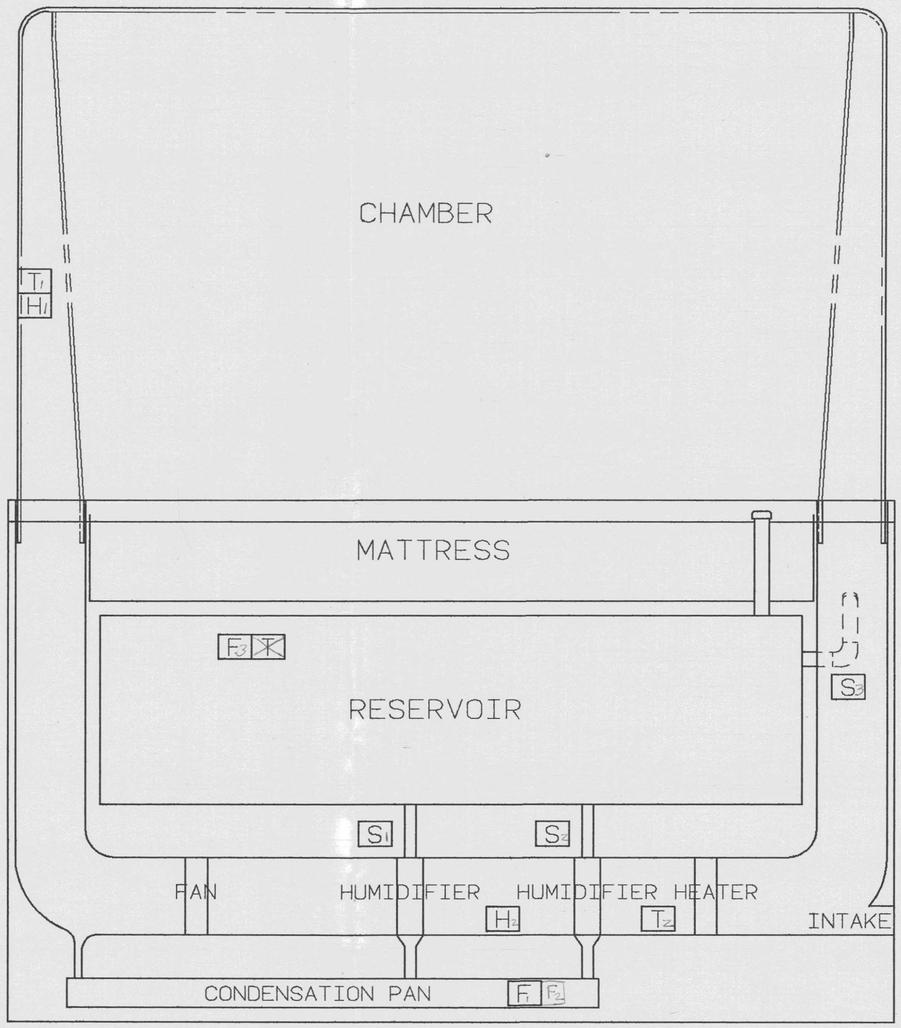
J.STEVENS	1

CADAM DRAWING
DO NOT REVISE MANUALLY

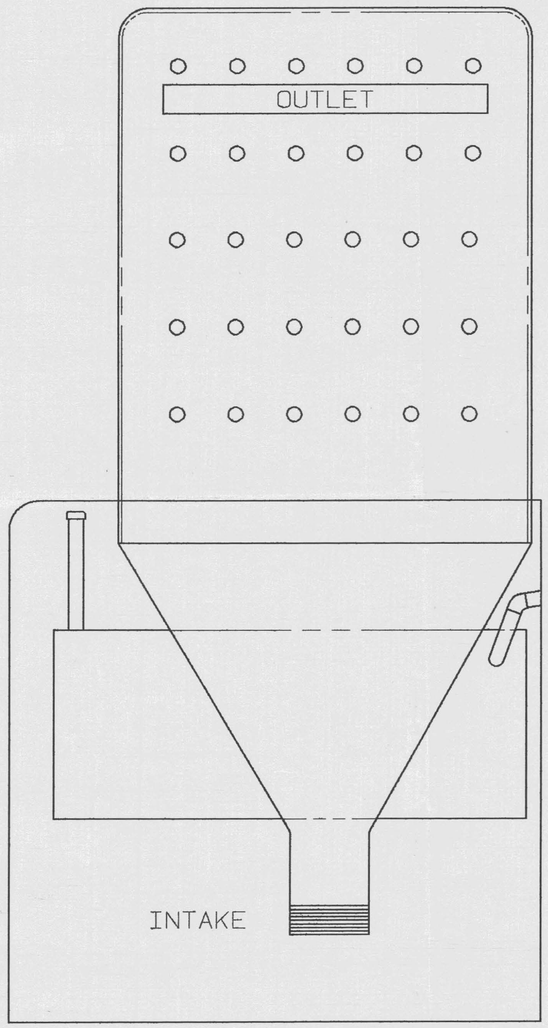
REV. LETTER	REVISION DESCRIPTION	DATE	BY

LEGEND

H	HUMIDISTAT
T	THERMOSTAT
F	FLOAT VALVE
S	SOLENOID VALVE



FRONT VIEW



END VIEW

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J.STEVENS		2	

CADAM DRAWING
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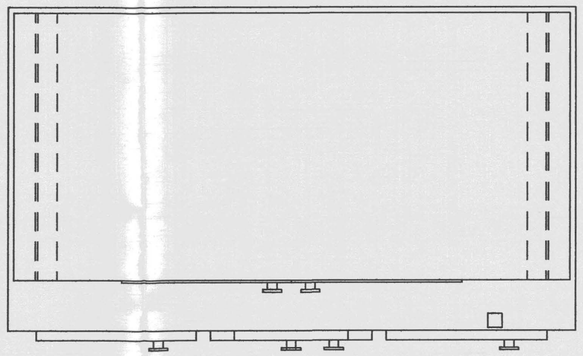

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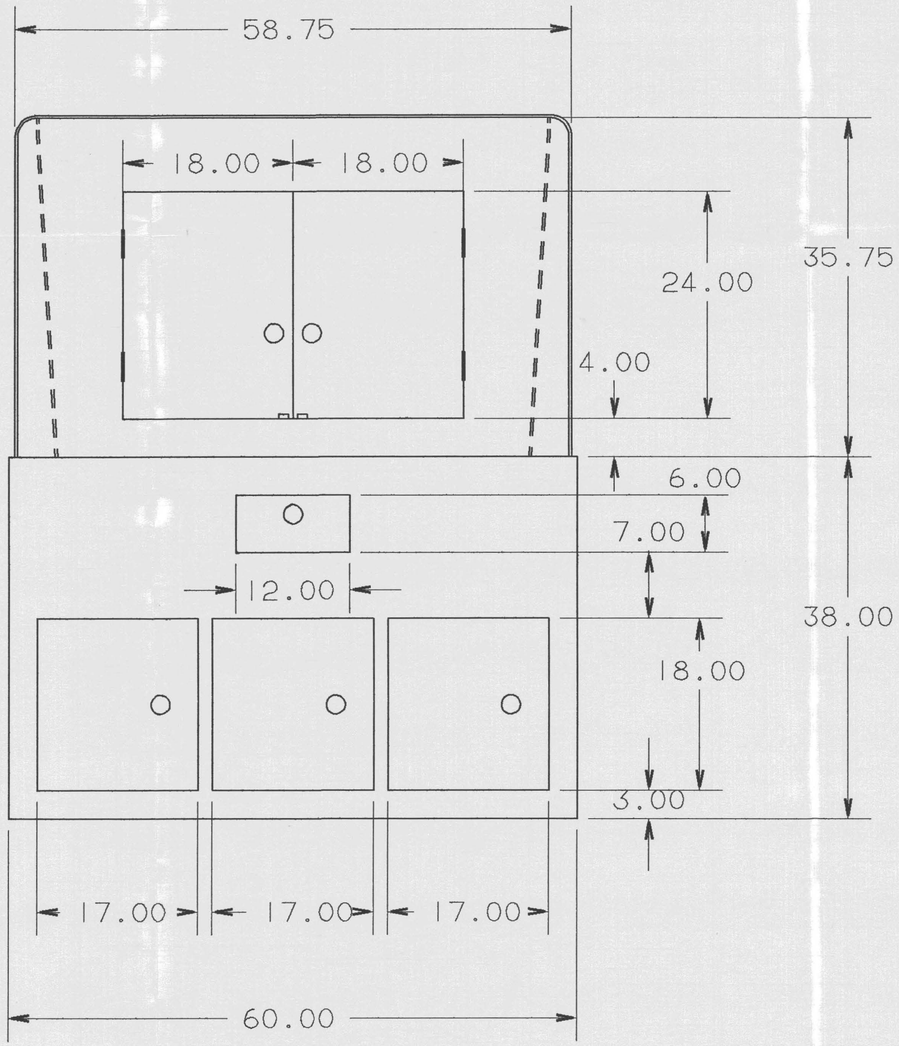
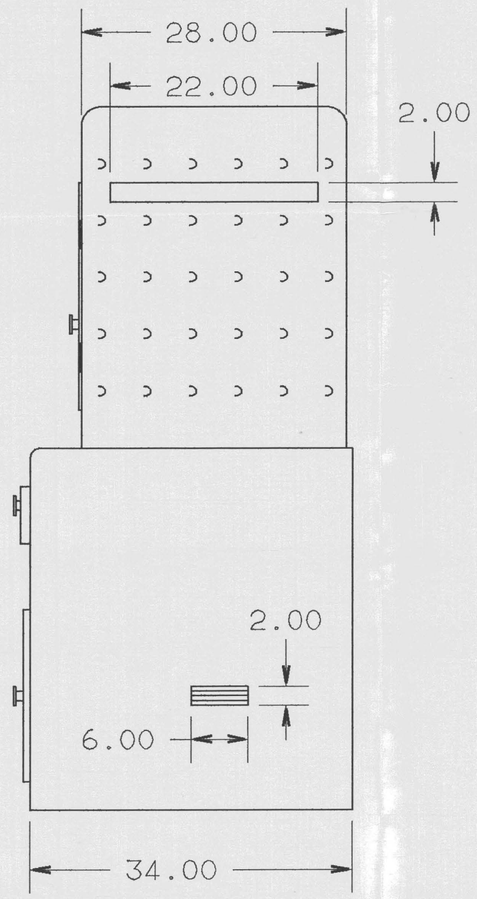
LOUVER HOLES: 1" DIA





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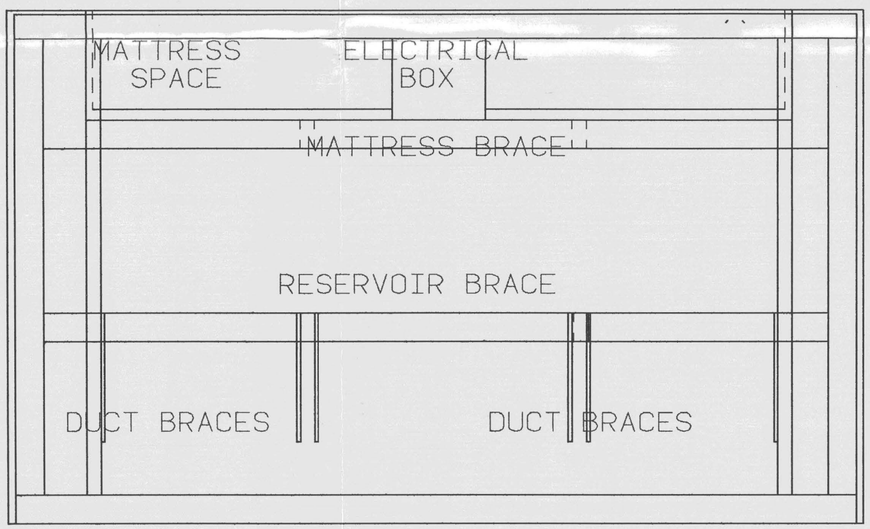
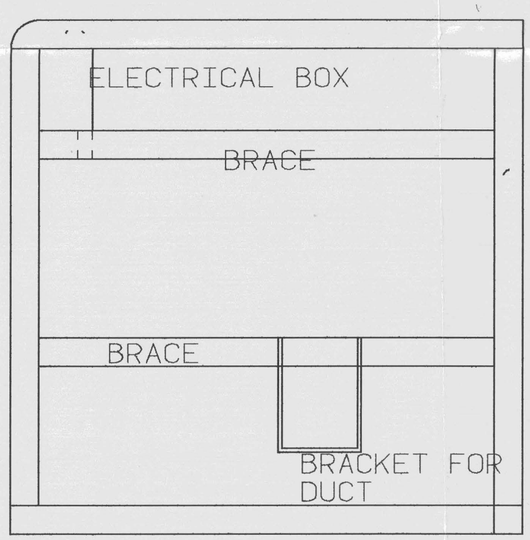
CADAM DRAWING
DO NOT REVISE MANUALLY

REV. LETTER	REVISION DESCRIPTION	DATE	BY

BEAMS/BRACES: 2X4 FIR STUDS
ELECTRICAL BOX ENCASEMENT: 26 GAGE SHEET METAL
MATTRESS SPACE ENCASEMENT: 3/4" PLYWOOD
OUTER ENCASEMENT: 1/2" PLYWOOD
DUCT BRACES: 1/2" U-SHAPED BRACES



FRONT VIEW



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COLLEGE OF ENGINEERING

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DATE 5/25/85	SCALE 1/12.0	DWG SIZE C	SHEET 1 OF 1

DRAWN BY	DRAWING NUMBER
J.STEVENS	6

CADAM DRAWING
DO NOT REVISE MANUALLY

LAST FILE = 85152 USER = STU165 DRAWID = ME-STRUCTURE -6 -
DATE = 6/03/85 TIME = 11.22 SCALE = 1.0000