

Contents

1	Introduction — 1
1.1	Boiler basics — 1
1.2	Boiler types — 2
1.3	Boiler arrangement — 3
1.4	Boiler designing sequence — 4
2	Input data — 6
3	Boiler heat duty — 8
4	Required fuel — 9
5	Forced draft fan discharge mass flow — 10
5.1	Barometric pressure — 10
5.2	Saturation pressure at actual temperature — 11
5.3	Moisture in air — 11
5.4	Total required air — 12
5.5	Excess air — 13
5.6	Total required combustion air — 14
5.7	Air density — 14
5.8	Standard combustion air flow — 15
5.9	Actual combustion air flow — 15
5.10	Forced draft fan discharge mass flow — 16
6	FD: Fan outlet duct design — 17
7	FD.Fan outlet duct pressure loss — 19
8	Furnace width and length — 21
8.1	Heat input to furnace — 21
8.2	Burner capacity selection — 21
8.3	Furnace width and length — 22
9	Furnace height — 25
9.1	Flue gas flow rate — 25
9.2	Flue gas molecular weight — 26
9.3	Actual flame temperature — 26
9.4	Flue gas temperature inside furnace — 27
9.5	Furnace pressure — 28
9.6	Flue gas inlet density — 28

9.7 Flue gas volumetric flow rate — 28

9.8 Furnace height — 29

10 Furnace volume — 31

11 Furnace exit temperature — 32

11.1 Furnace volumetric heat release — 32

11.2 Furnace heat surface area — 32

11.3 Furnace surface heat release — 32

11.4 Beam length — 33

11.5 Flue gas carbon dioxide vapor pressure — 33

11.6 Flue gas water vapor pressure — 34

11.7 Gas emissivity by carbon and water method — 34

11.8 Gas emissivity by Hottel's method — 35

11.9 Furnace exit temperature — 38

12 Combustion nonluminous heat transfer coefficient — 41

13 Combustion convection heat transfer coefficient — 42

13.1 Flue gas product properties — 42

13.2 Flue gas product gas mass velocity — 42

13.3 Flue gas product Reynolds number — 43

13.4 Flue gas product Prandtl number — 43

13.5 Flue gas product Nusselt number — 43

13.6 Combustion convection heat transfer coefficient — 44

14 Combustion outside heat transfer coefficient — 45

15 Average tube metal temperature — 46

15.1 Drum circulation water mass flow rate — 46

15.2 Drum each tube circulation water — 46

15.3 Inside gas film resistance — 47

15.4 Metal resistance — 49

15.5 Outside gas film resistance — 50

15.6 Heat flux — 50

15.7 Temperature drop across the gas film — 50

15.8 Temperature drop across the tube metal — 50

15.9 Temperature drop across the steam film — 50

15.10 Average tube metal temperature — 51

16 Furnace draft pressure drop — 52

- 16.1 Flue gas density — 52
- 16.2 Furnace volumetric flow rate — 53
- 16.3 Furnace flue gas velocity — 53
- 16.4 Head loss due to dimension change in furnace exit — 53
- 16.5 Furnace equivalent diameter — 54
- 16.6 Furnace equivalent length — 54
- 16.7 Reynolds number in furnace — 54
- 16.8 Friction factor in furnace — 55
- 16.9 Furnace draft pressure drop — 55

17 Boiler design pressure — 56

- 17.1 Steam drum saturated pressure and temperature — 56
- 17.2 Steam drum first safety valve setting pressure — 56
- 17.3 Steam drum second safety valve setting pressure — 57
- 17.4 Boiler design pressure — 57

18 Superheater package — 58

19 Superheater tube rows and deep number — 60

- 19.1 Superheater heat duty prediction — 60
- 19.2 Superheater tube thickness — 60
- 19.3 Superheater tube area — 61
- 19.4 Superheater tube rows and deep number — 61

20 Superheater convective heat transfer coefficient prediction — 62

- 20.1 Superheater flue gas outlet temperature prediction — 62
- 20.2 Log mean temperature difference prediction — 62
- 20.3 Superheater average flue gas temperature prediction — 63
- 20.4 Superheater average flue gas properties — 63
- 20.5 Superheater tube longitudinal and transverse pitch — 63
- 20.6 Superheater package long — 64
- 20.7 Superheater primary heat surface area — 64
- 20.8 Superheater gas mass velocity — 65
- 20.9 Superheater convective heat transfer coefficient — 65

21 Superheater uncontrolled outlet steam temperature prediction — 66

- 21.1 Superheater package performance prediction — 66
- 21.2 Superheater flue gas outlet temperature — 68
- 21.3 Superheater flue gas average temperature — 68
- 21.4 Superheater outlet steam temperature — 68
- 21.5 Each tube steam flow rate — 69

- 21.6 inside gas film resistance — 69
- 21.7 Metal resistance — 71
- 21.8 Outside gas film resistance — 71
- 21.9 Heat flux — 71
- 21.10 Temperature drop across the gas film — 72
- 21.11 Temperature drop across the tube metal — 72
- 21.12 Temperature Drop across the steam film — 72
- 21.13 Superheater uncontrolled outlet steam temperature prediction — 72

22 Superheater flue gas draft pressure drop — 73

- 22.1 Superheater flue gas density — 73
- 22.2 Superheater flue gas draft Reynolds number — 73
- 22.3 Superheater flue gas draft friction factor for inline arrangement — 73
- 22.4 Superheater flue gas draft pressure drop — 74

23 Superheater package total steam pressure drop — 75

- 23.1 Superheater inlet header diameter — 75
- 23.2 Superheater inlet header design pressure — 76
- 23.3 Superheater inlet header thickness by pressure — 76
- 23.4 Superheater inlet header thickness by tube holes — 76
- 23.5 Superheater inlet header selected thickness — 77
- 23.6 Superheater outlet header diameter & thickness — 77
- 23.7 Superheater inlet header Reynolds number — 77
- 23.8 Superheater inlet header friction factor — 78
- 23.9 Superheater inlet header steam pressure drop — 78
- 23.10 Superheater outlet header Reynolds number — 78
- 23.11 Superheater outlet header friction factor — 79
- 23.12 Superheater outlet header steam pressure drop — 79
- 23.13 Superheater tube bundle Reynolds number — 79
- 23.14 Superheater tube bundle friction factor — 80
- 23.15 Superheater tube bundle steam pressure drop — 80
- 23.16 Superheater package total steam pressure drop — 80

24 Steam and mud drum sizing — 81

- 24.1 Steam drum tube holes longitudinal and transverse pitch — 82
- 24.2 Steam drum thickness by pressure method — 82
- 24.3 Steam drum diagonal pitch — 83
- 24.4 Required longitudinal efficiency as per ASME SEC.1 PG-27.2.2 — 83
- 24.5 Actual longitude efficiency as per ASME SEC.1 PG-52.4 — 83
- 24.6 Required circumferential efficiency as per ASME SEC.1 PG-52.3 — 84
- 24.7 Actual circumferential efficiency as per ASME SEC.1 PG-52.3 — 84
- 24.8 Verification of the weakest ligament as per ASME SEC.1 PG-52.3 — 84

- 24.9 Diagonal efficiency as per ASME SEC.1 PG-52.3 — **84**
- 24.10 Maximum permissible ligament as per ASME SEC.1 PG-52.3 — **85**
- 24.11 Steam drum thickness by ligament — **86**
- 24.12 Steam drum selected thickness — **86**
- 24.13 Steam drum ellipsoidal head — **86**
- 24.14 Mud drum selected thickness — **88**
- 24.15 Mud drum ellipsoidal head — **88**

25 Bank tube average length — 89

- 25.1 Height to drilling tube inside steam drum — **89**
- 25.2 Height to drilling tube inside mud drum — **90**
- 25.3 Height between drum's center — **90**
- 25.4 Bank tube average length — **91**

26 Bank tube heat duty prediction — 92

27 Bank tube heat surface prediction — 94

- 27.1 Bank tube area width — **94**
- 27.2 Bank tube transverse pitch — **95**
- 27.3 Bank tube thickness — **96**
- 27.4 Bank tube area — **96**
- 27.5 Bank tube row number — **96**
- 27.6 Bank tube heat surface prediction — **98**

28 Steam drum outlet steam temperature — 99

- 28.1 Bank tube inlet flue gas properties — **99**
- 28.2 Bank tube flue gas mass velocity — **100**
- 28.3 Bank tube flue gas heat transfer coefficient — **100**
- 28.4 Bank tube package performance prediction — **100**
- 28.5 Bank tube bundle flue gas outlet temperature — **102**
- 28.6 Bank tube bundle flue gas average temperature — **102**
- 28.7 Steam drum primary outlet steam temperature — **102**
- 28.8 Drum each tube circulation water — **102**
- 28.9 Inside gas film resistance — **103**
- 28.10 Metal resistance — **104**
- 28.11 Outside gas film resistance — **104**
- 28.12 Heat flux — **105**
- 28.13 Temperature drop across the gas film — **105**
- 28.14 Temperature drop across the tube metal — **105**
- 28.15 Temperature drop across the steam film — **105**
- 28.16 Steam drum outlet steam temperature — **105**

29 Bank tube bundle flue gas draft pressure drop — 106

- 29.1 Bank tube bundle flue gas density — 106
- 29.2 Bank tube bundle flue gas average temperature viscosity — 106
- 29.3 Bank tube bundle flue gas Reynolds number — 106
- 29.4 Bank tube bundle flue gas friction factor — 107
- 29.5 Bank tube bundle flue gas draft pressure drop — 107

30 Bank tube duct flue gas draft pressure drop — 108

- 30.1 Bank tube flue gas volumetric flow rate — 108
- 30.2 Bank tube flue gas velocity — 108
- 30.3 Bank tube bundle exit flue gas density — 108
- 30.4 Bank tube bundle exit flue gas volumetric flow rate — 109
- 30.5 Bank tube bundle exit width — 109
- 30.6 Head loss due to change in bank tube duct contraction — 109
- 30.7 Head loss due to bank tube duct sudden contraction — 111
- 30.8 Bank tube duct flue gas draft pressure drop — 111

31 Bank tube total flue gas draft pressure drop — 112

32 Bank tube area length — 113

33 Furnace area length — 114

34 Boiler exit duct flue gas draft pressure drop — 115

- 34.1 Boiler exit duct dimension — 115
- 34.2 Boiler exit duct flue gas density — 115
- 34.3 Boiler exit duct equivalent diameter — 115
- 34.4 Boiler exit duct equivalent length — 116
- 34.5 Boiler exit duct flue gas Reynolds number — 116
- 34.6 Boiler exit duct flue gas friction factor — 116
- 34.7 Boiler exit duct flue gas draft pressure drop — 116

35 Bank tube bundle water pressure drop — 117

- 35.1 Bank tube bundle water flow — 117
- 35.2 Bank tube bundle water flow Reynolds number — 118
- 35.3 Bank tube bundle water flow friction factor — 118
- 35.4 Bank tube bundle water pressure drop — 118

36 Front and rear wall headers sizing — 119

- 36.1 Front and rear wall headers diameter — 119
- 36.2 Front and rear wall headers thickness — 120

37 Steam drum to superheater connection header sizing — 122

- 37.1 Steam drum to superheater pipe diameter — 122
- 37.2 Steam drum to superheater pipe thickness by pressure — 123
- 37.3 Steam drum to superheater pipe length — 123
- 37.4 Steam drum to superheater pipe steam flow Reynolds number — 124
- 37.5 Steam drum to superheater pipe steam flow friction factor — 124
- 37.6 Steam drum to superheater pipe steam flow pressure drop — 124

38 Economizer heat duty prediction — 125

39 Economizer tube rows deep no. — 126

- 39.1 Required feed water pump outlet pressure — 126
- 39.2 Economizer design pressure — 127
- 39.3 Economizer tube thickness — 127
- 39.4 Economizer tube area — 127
- 39.5 Economizer tubes row deep number — 128

40 Economizer tube arrangement — 129

41 Economizer tube solid or serrated fins — 130

42 Economizer convection heat transfer coefficient — 133

- 42.1 Economizer obstruction surface area — 133
- 42.2 Economizer gas mass velocity — 133
- 42.3 Economizer inlet flue gas properties — 133
- 42.4 Economizer flue gas Reynolds number — 134
- 42.5 Economizer convection heat transfer coefficient — 134

43 Economizer overall heat transfer coefficient — 139

- 43.1 Economizer fin efficiency — 139
- 43.2 Economizer fin effectiveness — 141
- 43.3 Economizer overall heat transfer coefficient — 141

44 Economizer tubes row number — 142

- 44.1 Economizer log mean temperature difference prediction — 142
- 44.2 Economizer heat surface prediction — 142
- 44.3 Economizer tubes row number — 142
- 44.4 Economizer final heat surface — 143

45 Economizer package performance — 144

- 45.1 Economizer package performance prediction — 144
- 45.2 Economizer outlet water temperature — 145
- 45.3 Economizer outlet flue gas temperature — 146

46 Economizer headers water pressure drop — 147

- 46.1 Economizer header diameter — 147
- 46.2 Economizer header design pressure — 147
- 46.3 Economizer header thickness — 148
- 46.4 Economizer header water flow Reynolds number — 148
- 46.5 Economizer header water flow friction factor — 148
- 46.6 Economizer headers water pressure drops — 149

47 Economizer tube bundle water pressure drops — 150

- 47.1 Economizer each row deep tubes length — 150
- 47.2 Economizer tube bundle flow Reynolds number — 150
- 47.3 Economizer tube bundle flow friction factor — 150
- 47.4 Economizer tube bundle water pressure drops — 151

48 Economizer package water pressure drop — 152

49 Economizer package flue gas draft pressure drops — 153

- 49.1 Economizer package flue gas average temperature — 153
- 49.2 Economizer package flue gas density — 153
- 49.3 Economizer gas side area — 153
- 49.4 Economizer package flue gas draft pressure drops — 153

50 Economizer outlet duct flue gas draft pressure drops — 156

- 50.1 Economizer outlet duct flue gas density — 156
- 50.2 Economizer outlet duct dimension — 156
- 50.3 Economizer outlet duct equivalent diameter — 156
- 50.4 Economizer outlet duct flue gas Reynolds number — 157
- 50.5 Economizer outlet duct flue gas friction factor — 157
- 50.6 Economizer outlet duct flue gas draft pressure drops — 157

51 Circulation ratio — 158

- 51.1 Furnace heat absorption — 159
- 51.2 Drum leaving steam enthalpy — 159
- 51.3 Downcomer mass flow — 159
- 51.4 Downcomer mixture enthalpy — 160

- 51.5 Downcomer specific volume — 160
- 51.6 Height from top of water wall to bottom — 160
- 51.7 Height of water from steam drum to bottom — 160
- 51.8 Boiler water available head — 161
- 51.9 Boiling height — 161
- 51.10 Gravity loss in boiling height — 161
- 51.11 Downcomer boiling height friction loss (single phase) — 162
- 51.12 Water wall except boiling height friction loss (two phase) — 164
- 51.13 Water wall tube acceleration loss (two phase) — 165
- 51.14 Riser tube gravity loss (two phase) — 166
- 51.15 Total two-phase pressure loss — 167
- 51.16 Riser circuit heated tube friction loss — 167
- 51.17 Total losses — 169
- 51.18 Circulation ratio test — 169

52 Flue gas stack sizing — 170

- 52.1 Flue gas stack diameter — 171
- 52.2 Flue gas stack height and active height — 171

53 Flue gas stack net available draft — 173

- 53.1 Stack flue gas Reynolds number — 173
- 53.2 Stack flue gas friction factor — 173
- 53.3 Stack flue gas draft pressure drop — 173
- 53.4 Stack flue gas available draft — 174
- 53.5 Stack flue gas net available draft — 174

54 Stack outlet flue gas temperature — 175

- 54.1 Stack flue gas convective heat transfer coefficient — 175
- 54.2 Stack heat surface loss — 175
- 54.3 Stack wall temperature drop across gas film — 176
- 54.4 Stack wall temperature drop across stack wall — 176
- 54.5 Stack inner wall temperature — 176
- 54.6 Stack outer wall temperature — 176
- 54.7 Stack outer wall heat transfer — 177
- 54.8 Stack flue gas temperature drop — 177
- 54.9 Barometric pressure — 177
- 54.10 Water dew point partial pressure — 178
- 54.11 Water dew point temperature — 178
- 54.12 Stack outlet flue gas temperature — 178

55 Stack outlet flue gas velocity — 179

56 Stack insulation thickness — 180

57 Force draft fan electric driver — 181

57.1 System gas pressure loss calculation — 181

57.2 Forced draft fan test block condition — 182

57.3 Forced draft fan brake horse power — 182

57.4 Forced draft fan required horse power — 183

57.5 Forced draft fan electric driver selection — 183

58 Pressure safety valve sizing — 185

58.1 Superheater safety valve sizing — 185

58.2 Boiler safety valve sizing — 187

59 Desuperheater water — 191

60 Boiler efficiency — 192

60.1 Boiler efficiency based on input-output method — 192

60.2 Boiler efficiency based on heat loss method — 193

61 Boiler package water weight — 196

61.1 Furnace total tangent tubes length (before lance) — 196

61.2 Bank tube package length — 197

61.3 Furnace total membrane tubes length — 197

61.4 Bank tube front and rear wall tubes length — 200

61.5 Furnace front and rear wall tubes length — 200

61.6 Bank tube total tubes length — 201

61.7 Boiler tubes water weight — 202

62 Boiler package water weight — 203

62.1 Steam and mud drum length — 203

62.2 Mud drum water weight — 203

62.3 Steam drum water weight — 203

62.4 Boiler package water weight — 204

63 Boiler holdup time (retention time) — 205

63.1 Maximum level fluctuation in steam drum according to demand — 205

63.2 Minimum required water up to drilling tubes inside steam drum — 205

63.3 Steam drum minimum diameter — 206

63.4 Maximum allowable level fluctuation in steam drum — 206

63.5 Maximum operating level fluctuation in steam drum — 207

- 63.6 Minimum level fluctuation in steam drum — 208
- 63.7 Minimum required operating water level in steam drum — 208
- 63.8 Boiler holdup time (retention time) — 208

64 Steam and mud drum weight — 212

- 64.1 Steam drum elliptical heads weight — 212
- 64.2 Steam drum weight — 212
- 64.3 Mud drum elliptical heads weight — 212
- 64.4 Mud drum weight — 213

65 Furnace total tube number — 214

66 Boiler total tube number — 215

67 Furnace total tubes weight — 216

- 67.1 Furnace total tangent wall tubes weight — 216
- 67.2 Furnace membrane wall tubes weight — 217
- 67.3 Furnace front and rear wall tubes weight — 217
- 67.4 Furnace total tubes weight — 217

68 Front and rear wall header weight — 218

69 Superheater package weight — 219

- 69.1 Superheater tubes weight — 219
- 69.2 Superheater inlet header weight — 220
- 69.3 Superheater outlet header weight — 220
- 69.4 Superheater package weight — 220

70 Steam drum to superheater connection header weight — 221

71 Bank tube package weight — 222

72 Economizer package weight — 223

- 72.1 Economizer fin plates weight — 223
- 72.2 Economizer fin tubes weight — 223
- 72.3 Economizer return elbows weight — 224
- 72.4 Economizer headers weight — 224
- 72.5 Economizer pressure parts weight — 225
- 72.6 Economizer package weight — 225

73 Stack weight — 226

74 Reports — 227

References — 241

Index — 243