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XV PROPERTIES OF GASES

Table of Contents

Section-Part	Title	Section-Part.Page
XV-0	List of Tables	XV-0.2
XV-0	List of Figures	XV-0.13
XV-1	Introduction	XV-1.1
XV-2	Properties of Nitrogen	XV-2.1
XV-3	Properties of Hydrogen	XV-3.1
XV-4	Properties of Helium	XV-4.1
XV-5	Properties of Oxygen	XV-5.1
XV-6	Properties of Carbon Dioxide	XV-6.1
XV-7	Properties of Perchloryl Fluoride	XV-7.1
XV-8	Properties of Chlorine Trifluoride	XV-8.1
XV-9	Properties of Hydrazine	XV-9.1
XV-10	Properties of Nitrogen (IV) Oxide	XV-10.1
XV-11	Properties of UDMH (Unsymmetrical Dimethyl-hydrazine)	XV-11.1
XV-12	Properties of Water	XV-12.1
XV-13	Properties of Propane	XV-13.1
XV-14	Properties of n-Butane	XV-14.1
XV-15	Properties of Ammonia	XV-15.1
XV-16	Properties of Hydrogen Peroxide	XV-16.1
XV-17	Properties of Freon-11 (CCl_3F)	XV-17.1
XV-18	Properties of Freon-12 (CCl_2F_2)	XV-18.1
XV-19	Properties of Freon-13 ($CClF_3$)	XV-19.1
XV-20	Properties of Freon-14 (CF_4)	XV-20.1

XV-0 LIST OF TABLES

Section-Part-Table	Title	Section-Part.Page
XV-2-1	Physical Constants of Nitrogen	XV-2.1
XV-2-1.1	Some Values of the Gas Constant, R, for Molecular Nitrogen	XV-2.2
XV-2-2	Vapor Pressure of Solid Nitrogen	XV-2.2
XV-2-3	Vapor Pressure of Liquid Nitrogen	XV-2.3
XV-2-4	Density of Liquid Nitrogen	XV-2.3
XV-2-5	Density of Saturated Liquid Nitrogen	XV-2.4
XV-2-6	Density of Saturated Nitrogen Gas	XV-2.4
XV-2-7	Density of Nitrogen	XV-2.5
XV-2-8	Surface Tension of Liquid Nitrogen Against Its Own Vapor	XV-2.5
XV-2-9	Viscosity of Liquid Nitrogen	XV-2.6
XV-2-10	Viscosity of Gaseous Nitrogen	XV-2.6
XV-2-11	Heat of Vaporization of Liquid Nitrogen	XV-2.7
XV-2-12	Heat Capacity of Solid and Liquid Nitrogen	XV-2.7
XV-2-13	Heat Capacity of Gaseous Nitrogen	XV-2.8
XV-2-14	Thermal Conductivity of Liquid Nitrogen	XV-2.9
XV-2-15	Thermal Conductivity of Gaseous Nitrogen	XV-2.9
XV-2-16	Total Enthalpy of Nitrogen	XV-2.10
XV-2-17	Low Frequency Velocity of Sound in Nitrogen	XV-2.10
XV-3-1	Physical Constants of Hydrogen	XV-3.1
XV-3-1.1	Some Values of the Gas Constant, R, for Molecular Hydrogen	XV-3.2
XV-3-2	Vapor Pressure of Liquefied Normal Hydrogen	XV-3.2
XV-3-3	Vapor Pressure of Solid Normal Hydrogen	XV-3.3

Tables

Section-Part-Table	Title	Section-Part.Page
XV-3-4	Density of Liquefied Normal Hydrogen	XV-3.3
XV-3-5	Density of Saturated Vapor of Liquefied Normal Hydrogen	XV-3.3
XV-3-6	Density of Normal Hydrogen	XV-3.4
XV-3-7	Surface Tension of Liquefied Normal Hydrogen	XV-3.4
XV-3-8	Viscosity of Liquefied Normal Hydrogen	XV-3.5
XV-3-9	Viscosity of Saturated Gaseous Normal Hydrogen	XV-3.5
XV-3-10	Heat of Vaporization of Liquefied Normal Hydrogen	XV-3.6
XV-3-11	Heat Capacity of Liquefied Normal Hydrogen at Saturation Pressure	XV-3.6
XV-3-12	Heat Capacity of Hydrogen Gas	XV-3.7
XV-3-13	Thermal Conductivity of Gaseous Normal Hydrogen	XV-3.8
XV-3-14	Thermal Conductivity of Liquefied Normal and Para Hydrogen	XV-3.9
XV-3-15	Total Enthalpy of Hydrogen	XV-3.10
XV-3-16	Low Frequency Velocity of Sound in Hydrogen	XV-3.11
XV-4-1	Physical Constants of Helium	XV-4.1
XV-4-1.1	Some Values of the Gas Constant, R, for Helium	XV-4.2
XV-4-2	Melting Point of Helium	XV-4.2
XV-4-3	Vapor Pressure of Liquefied Helium	XV-4.3
XV-4-4	Vapor Pressure of Solid Helium	XV-4.3
XV-4-5	Surface Tension of Saturated Liquid Helium Against Its Own Vapor	XV-4.4
XV-4-6	Density of Saturated Helium Liquid and Vapor	XV-4.4
XV-4-7	Density of Helium	XV-4.5
XV-4-8	Viscosity of Liquid Helium	XV-4.6
XV-4-9	Viscosity of Helium Gas at One Atmosphere	XV-4.6

Tables

Section-Part-Table	Title	Section-Part.Page
XV-4-10	Heat of Vaporization of Helium	XV-4.7
XV-4-11	Heat Capacity of Liquid Helium at Saturation Pressure	XV-4.7
XV-4-12	Heat Capacity of Gaseous Helium	XV-4.8
XV-4-13	Thermal Conductivity of Liquid Helium	XV-4.8
XV-4-14	Thermal Conductivity of Helium Gas at One Atmosphere	XV-4.9
XV-4-15	Total Enthalpy of Helium	XV-4.10
XV-4-16	Low Frequency Velocity of Sound in Helium	XV-4.11
XV-5-1	Physical Constants of Oxygen	XV-5.1
XV-5-1.1	Some Values of the Gas Constant, R, for Molecular Oxygen	XV-5.2
XV-5-2	Vapor Pressure of Liquid Oxygen	XV-5.2
XV-5-3	Vapor Pressure of Solid Oxygen	XV-5.3
XV-5-4	Density of Liquid Oxygen	XV-5.3
XV-5-5	Density of Oxygen	XV-5.4
XV-5-6	Surface Tension of Liquid Oxygen	XV-5.5
XV-5-7	Viscosity of Liquid Oxygen	XV-5.6
XV-5-8	Viscosity of Gaseous Oxygen	XV-5.6
XV-5-9	Heat Capacity of Liquid Oxygen	XV-5.7
XV-5-10	Heat Capacities of Oxygen	XV-5.8
XV-5-11	Thermal Conductivity of Gaseous Oxygen	XV-5.8
XV-5-12	Thermal Conductivity of Liquid Oxygen at Saturation Pressure	XV-5.9
XV-5-13	Heat of Vaporization of Liquid Oxygen	XV-5.9
XV-5-14	Total Enthalpy of Oxygen	XV-5.10
XV-5-15	Low Frequency Velocity of Sound in Oxygen	XV-5.11
XV-6-1	Physical Constants of Carbon Dioxide	XV-6.1
XV-6-1.1	Some Values of the Gas Constant, R, for Carbon Dioxide	XV-6.2

Tables

Section-Part-Table	Title	Section-Part.Page
XV-6-2	Vapor Pressure of Solid Carbon Dioxide	XV-6.2
XV-6-3	Vapor Pressure of Liquid Carbon Dioxide	XV-6.3
XV-6-4	Density of Carbon Dioxide (Saturated Liquid and Vapor	XV-6.3
XV-6-5	Density of Carbon Dioxide	XV-6.4
XV-6-6	Surface Tension of Liquid Carbon Dioxide	XV-6.5
XV-6-7	Heat of Vaporization of Carbon Dioxide	XV-6.5
XV-6-8	Heat Capacities of Gaseous Carbon Dioxide	XV-6.6
XV-6-9	Viscosity of Carbon Dioxide at Atmospheric Pressure	XV-6.7
XV-6-10	Thermal Conductivity of Gaseous Carbon Dioxide	XV-6.8
XV-6-11	Total Enthalpy of Carbon Dioxide	XV-6.9
XV-6-12	Low Frequency Velocity of Sound in Carbon Dioxide	XV-6.9
XV-7-1	General Properties of Perchloryl Fluoride	XV-7.1
XV-7-1.1	Some Values of the Gas Constant, R, for Perchloryl Fluoride	XV-7.1
XV-7-2	Vapor Pressure of Liquid Perchloryl Fluoride	XV-7.2
XV-7-3	Density of Liquid Perchloryl Fluoride	XV-7.3
XV-7-4	Density of Saturated Vapor of Perchloryl Fluoride	XV-7.3
XV-7-5	Viscosity of Liquid Perchloryl Fluoride	XV-7.4
XV-7-6	Heat Capacity of Saturated Liquid Perchloryl Fluoride	XV-7.4
XV-8-1	General Properties of Chlorine Trifluoride	XV-8.1
XV-8-1.1	Some Values of the Gas Constant, R, for Chlorine Trifluoride	XV-8.1
XV-8-2	Vapor Pressure of Chlorine Trifluoride	XV-8.2

Tables

Section-Part-Table	Title	Section-Part.Page
XV-8-3	Density of Liquid Chlorine Trifluoride	XV-8.3
XV-8-4	Surface Tension of Liquid Chlorine Trifluoride in Contact with its Vapor	XV-8.3
XV-8-5	Viscosity of Liquid Chlorine Trifluoride	XV-8.4
XV-8-6	Thermal Conductivity of Gaseous Chlorine Trifluoride	XV-8.4
XV-8-7	Heat Capacities of Solid and Liquid Chlorine Trifluoride	XV-8.5
XV-9-1	General Properties of Hydrazine	XV-9.1
XV-9-1.1	Some Values of the Gas Constant, R, for Hydrazine	XV-9.1
XV-9-2	Vapor Pressure of Anhydrous Hydrazine	XV-9.2
XV-9-3	Density of Liquid Hydrazine	XV-9.3
XV-9-4	Viscosity of Hydrazine	XV-9.3
XV-9-5	Heat Capacity of Liquid Hydrazine	XV-9.4
XV-9-6	Heat Capacity of Gaseous Hydrazine	XV-9.4
XV-9-7	Heat Capacity of Hydrazine at Constant Pressure	XV-9.5
XV-9-8	Thermal Conductivity of Hydrazine	XV-9.5
XV-10-1	General Properties of Nitrogen (IV) Oxide	XV-10.1
XV-10-2	Vapor Pressure of $N_2O_4 \rightleftharpoons 2NO_2$ System	XV-10.1
XV-10-3	Density of Equilibrium $N_2O_4 \rightleftharpoons 2NO_2$ Mixtures	XV-10.2
XV-10-4	Specific Heat of the $N_2O_4 \rightleftharpoons 2NO_2$ System at Constant Pressure	XV-10.2
XV-11-1	General Properties of UDMH (Unsymmetrical Dimethylhydrazine)	XV-11.1
XV-11-1.1	Some Values of the Gas Constant, R, for UDMH	XV-11.1
XV-11-2	Vapor Pressure of UDMH	XV-11.2
XV-11-3	Density of Liquid UDMH	XV-11.3

Tables

Section-Part-Table	Title	Section-Part.Page
XV-11-4	Viscosity of UDMH	XV-11.3
XV-11-5	Heat Capacity of UDMH	XV-11.4
XV-11-6	Thermal Conductivity of UDMH	XV-11.5
XV-12-1	Physical Constants of Water	XV-12.1
XV-12-1.1	Some Values of the Gas Content, R, for Water	XV-12.2
XV-12-2	Vapor Pressure of Ice	XV-12.2
XV-12-3	Vapor Pressure of Water	XV-12.3
XV-12-4	Density of Water	XV-12.3
XV-12-5	Density of Steam	XV-12.4
XV-12-6	Viscosity of Water	XV-12.5
XV-12-7	Viscosity of Steam at One Atmosphere	XV-12.5
XV-12-8	Heat Capacity of Ice	XV-12.6
XV-12-9	Heat Capacity of Water	XV-12.6
XV-12-10	Heat Capacity of Steam	XV-12.7
XV-12-11	Thermal Conductivity of Water	XV-12.7
XV-12-12	Thermal Conductivity of Steam	XV-12.8
XV-12-13	Heat of Vaporization of Water	XV-12.9
XV-12-14	Total Enthalpy Values and Specific Volumes for the Water System	XV-12.10
XV-12-15	Surface Tension of Water in Contact with Air	XV-12.11
XV-12-16	Low Frequency Velocity of Sound in Water Vapor	XV-12.11
XV-13-1	Physical Constants of Propane	XV-13.1
XV-13-1.1	Some Values of the Gas Constant, R, for Propane	XV-13.2
XV-13-2	Vapor Pressure of Liquid Propane	XV-13.2
XV-13-3	Density of Propane	XV-13.3
XV-13-4	Density of Liquid Propane	XV-13.4
XV-13-5	Density of Saturated Propane Vapor	XV-13.4
XV-13-6	Heat Capacity of Solid and Liquid Propane	XV-13.5

Tables

Section-Part-Table	Title	Section-Part.Page
XV-13-7	Heat Capacity of Propane Gas	XV-13.5
XV-13-8	Surface Tension of Liquid Propane	XV-13.6
XV-13-9	Viscosity of Liquid Propane	XV-13.6
XV-13-10	Viscosity of Propane at Various Pressures	XV-13.7
XV-13-11	Heat of Vaporization of Liquid Propane	XV-13.7
XV-13-12	Total Enthalpy Values and Specific Volumes for the Propane System	XV-13.8
XV-14-1	Physical Constants of n-Butane	XV-14.1
XV-14-1.1	Some Values of the Gas Constant, R, for n-Butane	XV-14.2
XV-14-2	Vapor Pressure of n-Butane	XV-14.2
XV-14-3	Density of n-Butane	XV-14.3
XV-14-4	Density of Liquid n-Butane	XV-14.4
XV-14-5	Density of Saturated n-Butane Vapor	XV-14.4
XV-14-6	Specific Heat of Liquid n-Butane	XV-14.5
XV-14-7	Specific Heat of n-Butane Gas	XV-14.5
XV-14-8	Heat of Vaporization of n-Butane	XV-14.6
XV-14-9	Viscosity of n-Butane	XV-14.6
XV-14-10	Viscosity of n-Butane at Various Pressures	XV-14.7
XV-14-11	Total Enthalpy and Specific Volume of the n-Butane System	XV-14.8
XV-15-1	Physical Constants of Ammonia	XV-15.1
XV-15-1.1	Some Values of the Gas Constant, R, for Ammonia	XV-15.2
XV-15-2	Vapor Pressure of Liquid Ammonia	XV-15-3
XV-15-3	Vapor Pressure of Solid Ammonia	XV-15.3
XV-15-4	Density of Saturated Ammonia Vapor	XV-15.4
XV-15-5	Density of Liquid Ammonia	XV-15.4
XV-15-6	Density of Ammonia	XV-15.5
XV-15-7	Surface Tension of Liquid Ammonia	XV-15.5

Tables

Section-Part-Table	Title	Section-Part.Page
XV-15-8	Viscosity of Liquid Ammonia (Saturated)	XV-15.6
XV-15-9	Viscosity of Liquid Ammonia	XV-15.6
XV-15-10	Viscosity of Gaseous Ammonia	XV-15.7
XV-15-11	Viscosity of Gaseous Ammonia at Constant Temperature	XV-15.7
XV-15-12	Heat Capacities of Solid and Liquid Ammonia	XV-15.8
XV-15-13	Heat Capacities of Ammonia Gas	XV-15.9
XV-15-14	Heat of Vaporization of Ammonia	XV-15.9
XV-15-15	Thermal Conductivity of Gaseous Ammonia (at Atmospheric Pressure)	XV-15.10
XV-15-16	Thermal Conductivity of Gaseous Ammon Ammonia as Function of Temperature	XV-15.10
XV-15-17	Total Enthalpy and Specific Volume of the Ammonia System	XV-15.11
XV-15-18	Low Frequency Velocity of Sound in Gaseous Ammonia	XV-15.12
XV-15-19	Low Frequency Velocity of Sound in Liquid Ammonia	XV-15.12
XV-16-1	General Properties of Hydrogen Peroxide	XV-16.1
XV-16-1.1	Some Values of the Gas Constant, R, for Hydrogen Peroxide	XV-16.1
XV-16-2	Total Vapor Pressure of 98-100% Hydrogen Peroxide Solutions	XV-16.2
XV-16-3	Density of Hydrogen Peroxide	XV-16.3
XV-16-4	Surface Tension of Hydrogen Peroxide	XV-16.3
XV-16-5	Viscosity of Hydrogen Peroxide	XV-16.3
XV-16-6	Heat Capacity of Solid Hydrogen Peroxide	XV-16.4
XV-16-7	Specific Heat of 98% Hydrogen Peroxide Solution	XV-16.5
XV-16-8	Heat Capacity of Hydrogen Peroxide Vapor	XV-16.5
XV-16-9	Thermal Conductivity of 98% Hydrogen Peroxide	XV-16.5

Tables

Section-Part-Table	Title	Section-Part.Page
XV-17-1	Physical Constants of Freon-11 (CCl_3F)	XV-17.1
XV-17-1.1	Some Values of the Gas Constant, R, for Freon-11	XV-17.2
XV-17-2	Vapor Pressure of Freon-11	XV-17.2
XV-17-3	Density of Freon-11	XV-17.3
XV-17-4	Viscosity of Saturated Liquid Freon-11	XV-17.4
XV-17-5	Viscosity of Freon-11 Vapor at One Atmosphere	XV-17.4
XV-17-6	Heat Capacity of Freon-11	XV-17.5
XV-17-7	Thermal Conductivity of Saturated Freon-11	XV-17.5
XV-17-8	Selected Values of Properties of Saturated Vapor of Freon-11	XV-17.6
XV-17-9.1	Properties of Superheated Vapor of Freon-11 at 1,2,3,5 psia	XV-17.8
XV-17-9.2	Properties of Superheated Vapor of Freon-11 at 10,20,30,40 psia	XV-17.10
XV-17-9.3	Properties of Superheated Vapor of Freon-11 at 50,60 psia	XV-17.12
XV-18-1	Physical Constants of Freon-12 (CCl_2F_2)	XV-18.1
XV-18-1.1	Some Values of the Gas Constant, R, for Freon-12	XV-18.2
XV-18-2	Vapor Pressure of Freon-12	XV-18.2
XV-18-3	Density of Freon-12	XV-18.3
XV-18-4	Viscosity of Saturated Liquid Freon-12	XV-18.4
XV-18-5	Viscosity of Freon-12 Vapor at One Atmosphere	XV-18.4
XV-18-6	Heat Capacity of Freon-12	XV-18.5
XV-18-7	Thermal Conductivity of Saturated Freon-12	XV-18.5
XV-18-8	Thermal Conductivity of Liquid Freon-12	XV-18.5
XV-18-9	Selected Values of Properties of Saturated Vapor of Freon-12	XV-18.6

Tables

Section-Part-Table	Title	Section-Part.Page
XV-18-10.1	Properties of Superheated Vapor of Freon-12 at 1,2,3 psia	XV-18.8
XV-18-10.2	Properties of Superheated Vapor of Freon-12 at 5,10,25 psia	XV-18.10
XV-18-10.3	Properties of Superheated Vapor of Freon-12 at 50,100,200 psia	XV-18.12
XV-18-10.4	Properties of Superheated Vapor of Freon-12 at 300,400,500 psia	XV-18.14
XV-18-10.5	Properties of Superheated Vapor of Freon-12 at 600 psia	XV-18.16
XV-19-1	Physical Constants of Freon-13 ($CClF_3$)	XV-19.1
XV-19-1.1	Some Values of the Gas Constant, R, for Freon-13	XV-19.2
XV-19-2	Vapor Pressure of Freon-13	XV-19.2
XV-19-3	Density of Freon-13	XV-19.3
XV-19-4	Viscosity of Freon-13	XV-19.4
XV-19-5	Heat Capacity of Freon-13	XV-19.4
XV-19-6	Thermal Conductivity of Gaseous Freon-13	XV-19.5
XV-19-7	Selected Values of Saturation Properties of Freon-13	XV-19.6
XV-19-8.1	Properties of Superheated Vapor of Freon-13 at 1,2,4 psia	XV-19.8
XV-19-8.2	Properties of Superheated Vapor of Freon-13 at 8,10,20 psia	XV-19.10
XV-19-8.3	Properties of Superheated Vapor of Freon-13 at 40,80,100 psia	XV-19.12
XV-19-8.4	Properties of Superheated Vapor of Freon-13 at 200,300,400 psia	XV-19.14
XV-20-1	Physical Constants of Freon-14 (CF_4)	XV-20.1
XV-20-1.1	Some Values of the Gas Constant, R, for Freon-14	XV-20.2
XV-20-2	Vapor Pressure of Freon-14	XV-20.2

Tables

Section-Part-Table	Title	Section-Part.Page
XV-20-3	Density of Freon-14	XV-20.3
XV-20-4	Viscosity of Freon-14	XV-20.4
XV-20-5	Heat Capacity of Freon-14	XV-20.4
XV-20-6	Thermal Conductivity of Gaseous Freon-14	XV-20.5
XV-20-7	Selected Values of Saturation Properties of Freon-14	XV-20.6
XV-20-8.1	Properties of Superheated Vapor of Freon-14 at 10,30,60 psia	XV-20.8
XV-20-8.2	Properties of Superheated Vapor of Freon-14 at 100,160,250 psia	XV-20.10
XV-20-8.3	Properties of Superheated Vapor of Freon-14 at 500,800,1000 psia	XV-20.12
XV-20-8.4	Properties of Superheated Vapor of Freon-14 at 2000,2800,4000 psia	XV-20.14

XV-0 LIST OF FIGURES

Section-Part-Figure	Title
XV-2-1	Vapor Pressure of Solid Nitrogen
XV-2-2	Vapor Pressure of Liquid Nitrogen
XV-2-3	Nitrogen, Constant Density as a Function of Pressure versus Temperature
XV-2-4	Surface Tension of Liquid Nitrogen Against its Own Vapor
XV-2-5	Viscosity of Liquid Nitrogen
XV-2-6	Viscosity of Gaseous Nitrogen
XV-2-7	Heat of Vaporization of Liquid Nitrogen
XV-2-8	Heat Capacity of Solid and Liquid Nitrogen
XV-2-9	Heat Capacity of Gaseous Nitrogen
XV-2-10	Specific Heat Ratios of Nitrogen
XV-2-11	Thermal Conductivity of Liquid Nitrogen
XV-2-12	Thermal Conductivity of Gaseous Nitrogen
XV-2-13	Total Enthalpy of Nitrogen
XV-2-14	Low Frequency Velocity of Sound in Nitrogen
XV-3-1	Vapor Pressure of Liquefied Normal Hydrogen
XV-3-2	Vapor Pressure of Solid Normal Hydrogen
XV-3-3	Hydrogen, Constant Density as a Function of Pressure versus Temperature
XV-3-4	Surface Tension of Liquefied Normal Hydrogen
XV-3-5	Viscosity of Liquefied Normal Hydrogen
XV-3-6	Viscosity of Saturated Gaseous Normal Hydrogen
XV-3-7	Heat of Vaporization of Liquefied Normal Hydrogen
XV-3-8	Heat Capacity of Liquefied Normal Hydrogen at Saturation Pressure
XV-3-9	Heat Capacity of Hydrogen Gas
XV-3-10	Specific Heat Ratios of Hydrogen
XV-3-11	Thermal Conductivity of Gaseous Normal Hydrogen
XV-3-12	Thermal Conductivity of Liquefied Normal and Para Hydrogen

Figures

Section-Part-Figure	Title
XV-3-13	Total Enthalpy of Hydrogen
XV-3-14	Low Frequency Velocity of Sound in Hydrogen (40-400°R)
XV-3-15	Low Frequency Velocity of Sound in Hydrogen (400-900°R)
XV-4-1	Melting Point of Helium
XV-4-2	Vapor Pressure of Liquefied Helium
XV-4-3	Vapor Pressure of Solid Helium
XV-4-4	Surface Tension of Liquid Helium Against its Own Vapor
XV-4-5	Helium, Constant Density as a Function of Pressure versus Temperature
XV-4-6	Viscosity of Liquid Helium
XV-4-7	Viscosity of Helium Gas at One Atmosphere
XV-4-8	Heat of Vaporization of Helium
XV-4-9	Heat Capacity of Liquid Helium at Saturation Pressure
XV-4-10	Specific Heat Ratios of Helium Gas
XV-4-11	Thermal Conductivity of Liquid Helium
XV-4-12	Thermal Conductivity of Helium Gas at One Atmosphere
XV-4-13	Total Enthalpy of Helium
XV-4-14	Low Frequency Velocity of Sound in Helium
XV-5-1	Vapor Pressure of Liquid Oxygen
XV-5-2	Vapor Pressure of Solid Oxygen
XV-5-3	Oxygen, Constant Density as a Function of Pressure versus Temperature
XV-5-4	Surface Tension of Liquid Oxygen
XV-5-5	Viscosity of Liquid Oxygen
XV-5-6	Viscosity of Gaseous Oxygen
XV-5-7	Heat Capacity of Liquid Oxygen
XV-5-8	Heat Capacities of Oxygen
XV-5-9	Specific Heat Ratios of Oxygen
XV-5-10	Thermal Conductivity of Gaseous Oxygen
XV-5-11	Heat of Vaporization of Liquid Oxygen

Figures

Section-Part-Figure	Title
XV-5-12	Total Enthalpy of Oxygen
XV-5-13	Low Frequency Velocity of Sound in Oxygen
XV-6-1	Vapor Pressure of Solid Carbon Dioxide
XV-6-2	Vapor Pressure of Liquid Carbon Dioxide
XV-6-3	Carbon Dioxide, Constant Density as a Function of Pressure versus Temperature
XV-6-4	Surface Tension of Liquid Carbon Dioxide
XV-6-5	Heat of Vaporization of Carbon Dioxide
XV-6-6	Heat Capacities of Gaseous Carbon Dioxide
XV-6-7	Specific Heat Ratios of Carbon Dioxide (0-40 Atm)
XV-6-8	Specific Heat Ratios of Carbon Dioxide (0-2 Atm)
XV-6-9	Viscosity of Carbon Dioxide
XV-6-10	Thermal Conductivity of Gaseous Carbon Dioxide
XV-6-11	Total Enthalpy of Carbon Dioxide
XV-6-12	Low Frequency Velocity of Sound in Carbon Dioxide
XV-7-1	Vapor Pressure of Perchloryl Fluoride
XV-7-2	Density of Liquid Perchloryl Fluoride
XV-7-3	Density of Saturated Vapor of Perchloryl Fluoride
XV-7-4	Viscosity of Liquid Perchloryl Fluoride
XV-7-5	Heat Capacity of Saturated Liquid Perchloryl Fluoride
XV-7-6	Heat Capacity of Gaseous Perchloryl Fluoride
XV-8-1	Vapor Pressure of Chlorine Trifluoride
XV-8-2	Density of Liquid Chlorine Trifluoride
XV-8-3	Surface Tension of Liquid Chlorine Trifluoride in Contact with its Vapor
XV-8-4	Viscosity of Liquid Chlorine Trifluoride
XV-8-5	Thermal Conductivity of Gaseous Chlorine Trifluoride
XV-8-6	Heat Capacities of Solid and Liquid Chlorine Trifluoride

Figures

Section-Part-Figure	Title
XV-9-1	Vapor Pressure of Liquid Hydrazine
XV-9-2	Density of Liquid Hydrazine
XV-9-3	Viscosity of Hydrazine
XV-9-4	Heat Capacity of Liquid Hydrazine
XV-9-5	Heat Capacity of Gaseous Hydrazine
XV-9-6	Heat Capacity of Hydrazine at Constant Pressure
XV-9-7	Thermal Conductivity of Hydrazine
XV-10-1	Vapor Pressure of $N_2O_4 \rightleftharpoons 2NO_2$ System
XV-10-2	Density of Equilibrium $N_2O_4 \rightleftharpoons 2NO_2$ Mixtures (Saturated Liquid)
XV-10-3	Density of Equilibrium $N_2O_4 \rightleftharpoons 2NO_2$ Mixtures (Saturated Gas)
XV-10-4	Specific Heat of the $N_2O_4 \rightleftharpoons 2NO_2$ System at Constant Pressure
XV-11-1	Vapor Pressure of UDMH
XV-11-2	Density of Liquid UDMH
XV-11-3	Viscosity of UDMH
XV-11-4	Heat Capacity of UDMH
XV-11-5	Thermal Conductivity of UDMH
XV-12-1	Vapor Pressure of Ice
XV-12-2	Vapor Pressure of Water
XV-12-3	Water, Constant Density as a Function of Pressure versus Temperature
XV-12-4	Viscosity of Water
XV-12-5	Viscosity of Steam at One Atmosphere
XV-12-6	Heat Capacity of Ice
XV-12-7	Heat Capacity of Water
XV-12-8	Heat Capacity of Steam
XV-12-9	Specific Heat Ratios of Water Vapor
XV-12-10	Thermal Conductivity of Water

Figures

Section-Part-Figure	Title
XV-12-11	Thermal Conductivity of Saturated Water Vapor
XV-12-12	Total Enthalpy of the Water System
XV-12-13	Specific Volume of Saturated Water Vapor over Ice and Water
XV-12-14	Surface Tension of Water in Contact with Air
XV-12-15	Low Frequency Velocity of Sound in Water
XV-12-16	Pressure of Saturated Water Vapor over Ice and Water
XV-13-1	Vapor Pressure of Liquid Propane
XV-13-2	Vapor Pressure of Liquid Propane (Low Range)
XV-13-3	Propane, Constant Density as a Function of Pressure versus Temperature
XV-13-4	Heat Capacity of Solid and Liquid Propane
XV-13-5	Heat Capacity of Propane Gas
XV-13-6	Specific Heat Ratios of Propane (0-2 Atm)
XV-13-7	Specific Heat Ratios of Propane (0-20Atm)
XV-13-8	Surface Tension of Liquid Propane
XV-13-9	Viscosity of Liquid Propane
XV-13-10	Heat of Vaporization of Liquid Propane
XV-13-11	Thermal Conductivity of Liquid Propane
XV-13-12	Total Enthalpy of the Propane System
XV-13-13	Specific Volume of Propane Vapor
XV-14-1	Vapor Pressure of n-Butane (330-390°R)
XV-14-2	Vapor Pressure of n-Butane (390-600°R)
XV-14-3	n-Butane, Constant Density as a Function of Pressure versus Temperature
XV-14-4	Specific Heat of Liquid n-Butane
XV-14-5	Specific Heat of n-Butane Gas
XV-14-6	Heat of Vaporization of n-Butane
XV-14-7	Viscosity of n-Butane
XV-14-8	Specific Heat Ratios of n-Butane (0-2 Atm)

Figures

Section-Part-Figure	Title
XV-14-9	Specific Heat Ratios of n-Butane (0-20 Atm)
XV-14-10	Thermal Conductivity of Liquid n-Butane
XV-14-11	Total Enthalpy of the n-Butane System
XV-14-12	Specific Volume of n-Butane Vapor
XV-15-1	Vapor Pressure of Liquid Ammonia
XV-15-2	Vapor Pressure of Solid Ammonia
XV-15-3	Ammonia, Constant Density as a Function of Pressure versus Temperature
XV-15-4	Surface Tension of Liquid Ammonia
XV-15-5	Heat Capacities of Solid and Liquid Ammonia
XV-15-6	Heat Capacity of Ammonia Gas
XV-15-7	Specific Heat Ratios of Ammonia (0-20 Atm)
XV-15-8	Specific Heat Ratios of Ammonia (0-3 Atm)
XV-15-9	Heat of Vaporization of Ammonia
XV-15-10	Viscosity of Gaseous and Liquid Ammonia
XV-15-11	Thermal Conductivity of Gaseous and Liquid Ammonia
XV-15-12	Total Enthalpy of the Ammonia System
XV-15-13	Specific Volume of Ammonia Vapor
XV-16-1	Total Vapor Pressure of 98-100% Hydrogen Peroxide Solutions
XV-16-2	Density of Hydrogen Peroxide
XV-16-3	Specific Heat of 98% Hydrogen Peroxide Solution
XV-16-4	Heat Capacity of Hydrogen Peroxide Vapor
XV-16-5	Thermal Conductivity of 98% Hydrogen Peroxide
XV-17-1	Vapor Pressure of Freon-11
XV-17-2	Freon-11, Constant Density as a Function of Pressure versus Temperature
XV-17-3	Viscosity of Saturated Liquid Freon-11
XV-17-4	Viscosity of Freon-11 Vapor at One Atmosphere
XV-17-5	Heat Capacity of Freon-11

Figures

Section-Part-Figure	Title
XV-17-6	Thermal Conductivity of Saturated Freon-11
XV-18-1	Vapor Pressure of Freon-12
XV-18-2	Freon-12, Constant Density as a Function of Pressure versus Temperature
XV-18-3	Viscosity of Saturated Liquid Freon-12
XV-18-4	Viscosity of Vapor of Freon-12 at One Atmosphere
XV-18-5	Heat Capacity of Freon-12
XV-18-6	Specific Heat Ratios of Freon-12 (0-40 Atm)
XV-18-7	Specific Heat Ratios of Freon-12 (0-2 Atm)
XV-18-8	Thermal Conductivity of Saturated Freon-12
XV-18-9	Thermal Conductivity of Liquid Freon-12
XV-19-1	Vapor Pressure of Freon-13
XV-19-2	Freon-13, Constant Density as a Function of Pressure versus Temperature
XV-19-3	Viscosity of Freon-13
XV-19-4	Heat Capacity of Freon-13
XV-19-5	Specific Heat Ratios of Freon-13 (0-20 Atm)
XV-19-6	Specific Heat Ratios of Freon-13 (0-2 Atm)
XV-19-7	Thermal Conductivity of Gaseous Freon-13
XV-20-1	Vapor Pressure of Freon-14
XV-20-2	Freon-14, Constant Density as a Function of Pressure versus Temperature
XV-20-3	Viscosity of Freon-14
XV-20-4	Heat Capacity of Freon-14
XV-20-5	Thermal Conductivity of Gaseous Freon-14

XV-I INTRODUCTION

The "Properties of Gases" Section contains thermodynamic and physical property data for gases which are used for pressurizing spacecraft or missile systems or which may be used in attitude control systems. Data for other materials, such as Hydrogen Peroxide, UDMH, etc., are also included inasmuch as these materials might conceivably be used in pressurization systems.

Of the nineteen gases considered in the original guidebook only thirteen were selected by IIT Research Institute to be updated and expanded. These gases are Nitrogen, Hydrogen, Helium, Oxygen, Carbon Dioxide, Water, Propane, n-Butane, Ammonia and the four Freons. It was felt that the selected gases would be those fluids most likely used as pressurizing media in aerospace applications. The revised edition has added data that were missing in the original wherever such data were found.

The remaining six fluids - Perchloryl Fluoride, Chlorine Trifluoride, Hydrazine, Nitrogen Tetroxide, UDMH, and Hydrogen Peroxide - were not updated or expanded in any way. Other than replotting some of the data using English rather than metric units the data are as Stanford Research Institute prepared them.

The major change in this Section is the graphical presentation of density data of the 13 fluids considered. Complete, reliable density data are available for Ammonia, Carbon Dioxide, Nitrogen, Propane and Water in the pressure range of 0 to 6000 psia and in the appropriate temperature range. These data are presented graphically with the density values as isometrics to improve the accuracy of the graph construction and to simplify interpolation.

The data for Butane, Hydrogen, Oxygen, and Helium were not complete for the entire temperature and pressure range. The density values were plotted isometrically and extrapolated to the limits through application of the theorem of corresponding states. The extrapolation is considered valid as there were a few isolated data points to confirm the higher temperature and pressure points.

Only minimal data were available for the Freons. By treating each Freon as a model for the others and applying the theorem of corresponding states, all the available data were utilized to simultaneously construct the four graphs. These graphs are predominantly theoretical and therefore the density values at high pressures must be treated cautiously. Tables of selected values for the various properties considered for the Freons are presented. These data were taken from the DuPont Bulletins on the Freons and should be referred to when more extensive data are required. The specific bulletins are listed in the References.

At low temperatures and high pressures, the Helium data were calculated from the National Bureau of Standards equation of state. These extrapolations were shown to have a 5% accuracy by M.I.T.

In general, the graphs are a useful presentation of the desired information. The area adjacent to the critical point is the most difficult to interpret; this is also the area of least accurate data. Fortunately, since this area is the one in which the density has maximum temperature and pressure dependency, it is the least desirable operational area.

In addition to the revised density graphs the majority of the original graphs for all 19 gases have been replotted to facilitate their use by changing the temperature scale from ^{o}K to ^{o}R and to provide easily readable scales.

Table XV-2-1

PHYSICAL CONSTANTS

OF

NITROGEN

		REF.
Molecular Weight	28.016	9
Boiling Point @ 1 atm.	-320.46°F	9
Freezing Point @ 1 atm.	-345.8°F	9
Specific Volume @ 70°F, 1 atm.	13.8 cu-ft/lb	9
Vapor Pressure @ 120°K	364.6 psia	5
Specific Gravity, (Air = 1)	0.09670	9
Density		
Liquid		
Gas @ 70°F, 1 atm.	0.07247 lb/cu-ft	9
Critical Temperature	-232.87°F	9
Critical Pressure	492.45 psia	9
Critical Density	19.42 lb/cu-ft	9
Latent Heat of Vaporization @ b.p.	85.84 Btu/lb	9
Latent Heat of Fusion @ m.p.	11.05 Btu/lb	9
Specific Heat of Gas		
c_p @ 60°F	0.247 Btu/lb-°F	9
c_v @ 60°F	0.1765 Btu/lb-°F	9
Specific Heat Ratio, c_p/c_v	1.404	9
Thermal Conductivity @ 60°F	0.01462 Btu/hr-ft-°F	9
Viscosity		
Liquid		
Gas @ 59°F	1.17×10^{-5} lb/ft-sec	9
Solubility in Water @ 32°F	0.026 by volume	10
Surface Tension @ -297.4°F	4.523×10^{-4} lb/ft	11

Table XV-2-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR MOLECULAR NITROGEN
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.92892	3.02624	2225.98	43.0434
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0469164	0.0484753	35.6565	0.689484
lb mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.62718	1.68124	1236.66	23.9130
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0260647	0.0269307	19.8092	0.383047
lb mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-2-2

VAPOR PRESSURE OF SOLID NITROGEN (Ref. 5)

TEMPERATURE		VAPOR PRESSURE		
°K	°R	mm Hg	psia	atm
52	93.6	5.666	0.1096	0.0075
54	97.2	10.21	0.1974	0.0134
56	100.8	17.64	0.3411	0.0232
58	104.4	29.35	0.5675	0.0386
60	108.0	47.21	0.9129	0.0621
62	111.6	73.64	1.424	0.0969
63.15	113.67	93.88	1.815	0.1235

$$\log P_{mm} = 7.65894 - 359.093/T$$

(See Figure XV-2-1)

Table XV-2-3

VAPOR PRESSURE OF LIQUID NITROGEN (Ref. 5)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
^oK	^oR	atm	^oK	^oR	atm
62.50	112.50	0.1096	88.89	160.00	3.217
64.52	116.13	0.1576	93.02	167.44	4.568
65.57	118.03	0.1889	97.56	175.61	6.47
68.97	124.14	0.3244	100.00	180.00	7.70
71.43	128.57	0.465	105.26	189.47	10.91
75.47	135.85	0.793	111.11	200.00	15.47
78.43	141.18	1.127	116.28	209.30	20.50
80.00	144.00	1.341	120.48	216.87	25.42
83.33	150.00	1.896	125.00	225.00	31.71
86.96	156.52	2.693	128.21	230.77	37.04

(See Figure XV-2-2)

Table XV-2-4

DENSITY OF LIQUID NITROGEN (Ref. 6)

TEMPERATURE		DENSITY
^oK	^oR	lb/ft^3
63.9	115	54.4
64.3	115.8	54.2
64.8	116.8	53.9
65.0	117	54.1
68.0	122.3	53.1
69.1	124.4	52.8
69.2	124.5	53.1
71.0	127.9	52.2
71.4	128.3	52.2
74.0	136.9	51.4
76.1	137.0	51.5
77.0	138.8	50.6
77.3	139.2	50.5
77.4	139.3	50.4

Table XV-2-5

DENSITY OF SATURATED LIQUID NITROGEN (Ref. 2)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
^oK	^oR	lb/ft^3	^oK	^oR	lb/ft^3
77.4	139.35	50.38	105.5	190	40.92
80.5	145	49.55	108.2	195	39.68
83.3	150	48.71	111.1	200	38.40
86.1	155	47.85	113.9	205	37.04
88.8	160	47.17	116.7	210	35.46
91.7	165	46.06	119.3	215	33.37
94.4	170	45.15	122.1	220	30.88
97.2	175	44.19	125.0	225	27.60
100.0	180	43.18	126.1	227.0	19.64
102.8	185	42.09			

Table XV-2-6

DENSITY OF SATURATED NITROGEN GAS (Ref. 2)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
^oK	^oR	lb/ft^3	^oK	^oR	lb/ft^3
77.5	139.5	0.2879	105.56	190	2.8818
80.56	145	0.3978	108.33	195	3.3795
83.33	150	0.5179	111.11	200	4.1701
86.11	155	0.6658	113.89	205	5.0000
88.89	160	0.8418	116.67	210	6.0533
91.67	165	1.0617	119.44	215	7.4184
94.44	170	1.3228	122.22	220	9.2593
97.22	175	1.6170	125.00	225	11.990
100.00	180	1.9697	126.11	227	19.640
102.78	185	2.3929			

Table XV-2-7

DENSITY OF NITROGEN (Ref. 12,13,14)

DENSITY-lb/ft^3							
PRESSURE psia \ TEMP. °R	200	300	400	500	600	700	800
100	1.30	0.86	0.65	0.50	0.48	0.39	0.33
500	39.80	5.22	3.54	2.71	2.20	1.85	1.60
1000	41.44	12.25	7.10	5.32	4.34	3.68	3.18
2000	43.60	25.16	14.55	10.45	8.33	7.03	6.09
3000	45.00	31.16	20.34	15.00	12.05	10.18	8.75
4000	46.24	34.68	24.90	18.86	15.25	12.92	11.29
5000	47.20	36.90	28.13	22.00	18.10	15.40	13.52
6000	48.00	38.57	30.70	24.90	20.60	17.67	15.48

(See Figure XV-2-3)

Table XV-2-8

SURFACE TENSION OF LIQUID NITROGEN
AGAINST ITS OWN VAPOR (Ref. 1)

TEMPERATURE		SURFACE TENSION	TEMPERATURE		SURFACE TENSION
°K	°R	dynes/cm	°K	°R	dynes/cm
68	122.40	11.00	80	144.0	8.27
69	124.20	10.76	81	145.8	8.06
70	126.00	10.53	82	147.6	7.84
71	127.80	10.30	83	149.4	7.63
72	129.6	10.07	84	151.2	7.42
73	131.4	9.84	85	153.0	7.20
74	133.2	9.62	86	154.8	6.99
75	135.0	9.39	87	156.6	6.78
76	136.8	9.16	88	158.4	6.57
77	138.6	8.94	89	160.2	6.37
78	140.4	8.72	90	162.0	6.16
79	142.2	8.50			

(See Figure XV-2-4)

Table XV-2-9

VISCOSITY OF LIQUID NITROGEN (Ref. 4)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises
111.7	201.06	0.074
77.3	139.14	0.158
76.1	136.98	0.165
71.4	128.52	0.209
69.25	124.65	0.228
69.1	124.38	0.231
64.8	116.64	0.284
64.3	115.74	0.290
63.9	115.02	0.292

(See Figure XV-2-5)

Table XV-2-10

VISCOSITY OF GASEOUS NITROGEN (Ref. 5)

TEMPERATURE		ABSOULTE VISCOSITY— centipoises		
°K	°R	1 atm	10 atm	100 atm
100	180	0.00687		
150	270	0.0101		
200	360	0.0129		
250	450	0.0155		
300	540	0.0179	0.0179	0.0197
350	630	0.0200	0.0201	0.0215
400	720	0.0220	0.0221	0.0233
450	810	0.0239	0.0240	0.0250
500	900	0.0257	0.0258	0.0267

(See Figure XV-2-6)

Table XV-2-11

HEAT OF VAPORIZATION OF LIQUID NITROGEN (Ref. 2)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
77.5	139.5	85.64	105.56	190	63.37
80.56	145	84.02	108.33	195	59.85
83.33	150	82.32	111.11	200	56.01
86.11	155	80.51	113.89	205	51.68
88.89	160	78.59	116.67	210	46.82
91.67	165	76.54	119.44	215	40.96
94.44	170	74.36	122.22	220	33.75
97.22	175	72.02	125.00	225	23.78
100.00	180	69.45	126.11	227	00.0
102 78	185	66.58			

(See Figure XV-2-7)

Table XV-2-12

HEAT CAPACITY OF SOLID AND LIQUID NITROGEN (Ref. 3)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb-°R	°K	°R	Btu/lb-°R
15.82	28.48	0.1115	53.55	96.39	0.3662
17.66	31.79	0.1371	55.88	100.58	0.3726
19.51	35.12	0.1634	57.99	104.38	0.3801
21.94	39.49	0.1944	61.40	110.52	0.3958
24.49	44.08	0.2260	61.41	110.54	.0.3951
24.85	44.73	0.2277	63.14	113.65	Melting Point
27.14	48.85	0.2559	65.02	117.04	0.4758
28.32	50.98	0.2691	68.41	123.14	0.4801
29.89	53.80	0.2904	70.28	126.50	0.4801
31.29	56.32	0.3085	72.69	130.84	0.4840
32.84	59.11	0.3354	74.57	134.23	0.4851
34.42	61.96	0.3669	76.58	137.84	0.4883
34.68	62.42	0.3744	77.74	139.93	0.4869
35.05	63.09	0.3869			
35.33	63.59	0.3808			
35.61	64.10	Transition			
39.13	70.43	0.3194			
43.27	77.89	0.3328			
48.07	86.53	0.3481			
51.88	93.38	0.3602			

(See Figure XV-2-8)

Table XV-2-13

HEAT CAPACITY OF GASEOUS NITROGEN (Ref. 5)

TEMPERATURE		HEAT CAPACITY, C_p—Btu/lb-°R				
°K	°R	1 atm	10 atm	40 atm	70 atm	100 atm
100	180	0.2561				
110	198	0.2530				
120	216	0.2518				
130	234	0.2511				
140	252	0.2505	0.2806			
150	270	0.2501	0.2725			
160	288	0.2498	0.2677			
170	306	0.2496	0.2644			
180	324	0.2494	0.2619	0.3205		
190	342	0.2493	0.2600	0.3065	0.3699	
200	360	0.2491	0.2585	0.2968	0.3445	0.3998
210	378	0.2490	0.2573	0.2895	0.3273	0.3679
220	396	0.2489	0.2562	0.2839	0.3149	0.3466
230	414	0.2489	0.2554	0.2795	0.3055	0.3310
240	432	0.2488	0.2547	0.2759	0.2982	0.3197
250	450	0.2488	0.2541	0.2729	0.2923	0.315
260	468	0.2487	0.2535	0.2705	0.2875	0.3034
270	486	0.2487	0.2531	0.2683	0.2835	0.2977
280	504	0.2487	0.2527	0.2665	0.2802	0.2926
290	522	0.2487	0.2524	0.2650	0.2774	0.2885
300	540	0.2487	0.2521	0.2636	0.2749	0.2850
310	558	0.2487	0.2519	0.2625	0.2728	0.2820
320	576	0.2487	0.2517	0.2615	0.2709	0.2795
330	594	0.2488	0.2515	0.2606	0.2693	0.2772
340	612	0.2488	0.2514	0.2598	0.2679	0.2752
350	630	0.2489	0.2513	0.2592	0.2667	0.2735
360	648	0.2490	0.2512	0.2586	0.2656	0.2720
370	666	0.2491	0.2512	0.2581	0.2646	0.2706
380	684	0.2492	0.2512	0.2577	0.2638	0.2694
390	702	0.2494	0.2512	0.2573	0.2631	0.2684
400	720	0.2496	0.2513	0.2570	0.2624	0.2674
410	738	0.2497	0.2514	0.2568	0.2619	0.2666
420	756	0.2500	0.2515	0.2566	0.2614	0.2659
430	774	0.2502	0.2517	0.2565	0.2611	0.2653
440	792	0.2504	0.2518	0.2564	0.2607	0.2647
450	810	0.2507	0.2520	0.2564	0.2605	0.2643
460	828	0.2510	0.2523	0.2564	0.2603	0.2639
470	846	0.2513	0.2525	0.2564	0.2601	0.2636
480	864	0.2516	0.2528	0.2565	0.2600	0.2633
490	882	0.2519	0.2531	0.2566	0.2600	0.2632
500	900	0.2523	0.2534	0.2568	0.2600	0.2630

(See Figure XV-2-9)

Table XV-2-14

THERMAL CONDUCTIVITY OF LIQUID NITROGEN (Ref.7)

TEMPERATURE		THERMAL CONDUCTIVITY
^{o}K	^{o}R	Btu/hr-ft-^{o}R
60	108.0	0.09402
70	126.0	0.08619
80	144.0	0.07836
90	162.0	0.07053
100	180.0	0.06270
110	198.0	0.05487

(See Figure XV-2-11)

Table XV-2-15

THERMAL CONDUCTIVITY OF GASEOUS NITROGEN (Ref.15)

TEMPERATURE		THERMAL CONDUCTIVITY— Btu/ft-hr-^{o}R			
^{o}K	^{o}R	1 atm	10 atm	100 atm	300 atm
100	180	.005319	.054929*	.063600	.074587
120	216	.006534	.007748*	.047412	.061867
140	252	.007517	.008210	.033535	.050881
160	288	.008410	.009193	.023706	.043365
180	324	.009656	.010176	.019658	.037004
200	360	.010581	.011159	.017346	.033535
300	540	.015091		.018502	
400	720	.019080		.021393	
600	1080	.026019		.027753	
800	1440	.031801		.034113	

* Indicates a liquid below its critical pressure.

Table XV-2-16

TOTAL ENTHALPY OF NITROGEN (Ref. 5)

TEMPERATURE		TOTAL ENTHALPY—Btu/lb			
°K	°R	0.01 atm	1 atm	10 atm	100 atm
100	180	44.531	43.876		
120	216	53.468	52.994		
140	252	62.400	62.034	58.417	
160	288	71.333	71.040	68.245	
180	324	80.266	80.026	77.767	
200	360	89.199	88.997	87.129	67.6
220	396	98.132	98.242	96.389	80.9
240	432	107.07	106.92	105.58	93.1
260	468	116.00	115.88	114.73	104.0
280	504	124.94	124.83	123.84	114.9
300	540	133.88	133.78	132.93	125.3
320	576	142.82	142.74	142.00	135.5
340	612	151.76	151.69	151.05	145.5
360	648	160.72	160.65	160.10	155.3
380	684	169.67	169.65	169.14	165.1
400	720	178.64	178.60	178.18	174.7
420	756	187.63	187.59	187.24	184.34
440	792	196.63	196.59	196.29	193.90
460	828	205.65	205.62	205.37	203.40
480	864	214.69	214.67	214.46	212.89
500	900	223.82	223.73	223.57	222.37

(See Figure XV-2-13)

Table XV-2-17

LOW FREQUENCY VELOCITY OF SOUND IN NITROGEN (Ref. 5)

TEMPERATURE		VELOCITY—ft/sec			
°K	°R	0.01 atm	1 atm	10 atm	100 atm
100	180	669.	661.		
120	216	733.	729.		
140	252	792.	788.		
160	288	846.	843.	829.	
180	324	898.	896.	888.	
200	360	945.	945.	941.	1040.
220	396	992.	992.	991.	1083.
240	432	1036.	1036.	1037.	1128.
260	468	1078.	1078.	1081.	1161.
280	504	1119.	1120.	1123.	1207.
300	540	1159.	11.59	1163.	1248.
320	576	1196.	1196.	1202.	1289.
340	612	1233.	1233.	1239.	1327.
360	648	1268.	1269.	1276.	1364.
380	684	1302.	1303.	1310.	1400.
400	720	1335.	1337.	1344.	1435
420	756	1369.	1370.	1377.	1467.
440	792	1401.	1401.	1408.	1499.
460	828	1432.	1433.	1439.	1530.
480	864	1461.	1461.	1470.	1560.
500	900	1490.	1491.	1499.	1589.

(See Figure XV-2-14)

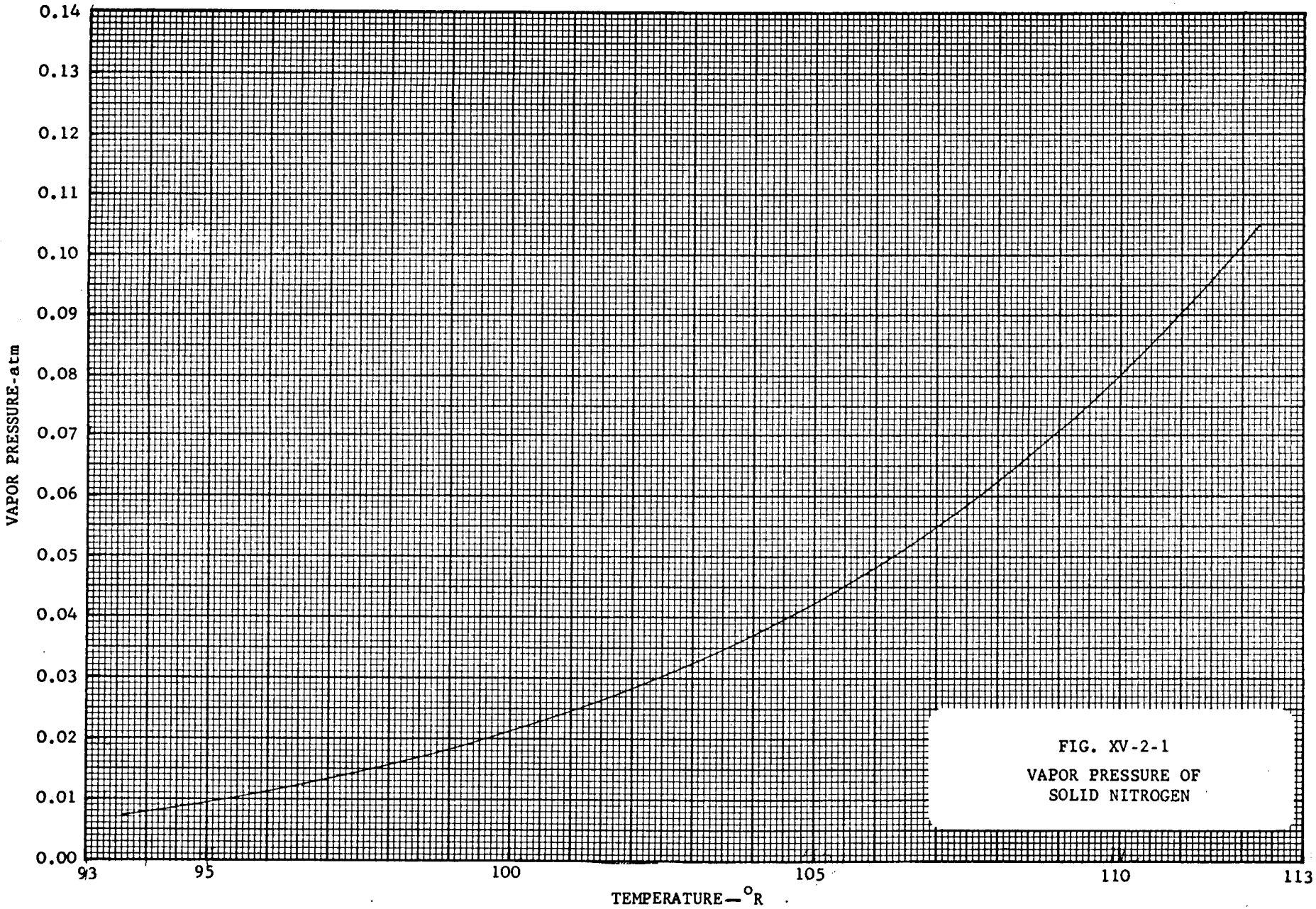


FIG. XV-2-1
VAPOR PRESSURE OF
SOLID NITROGEN

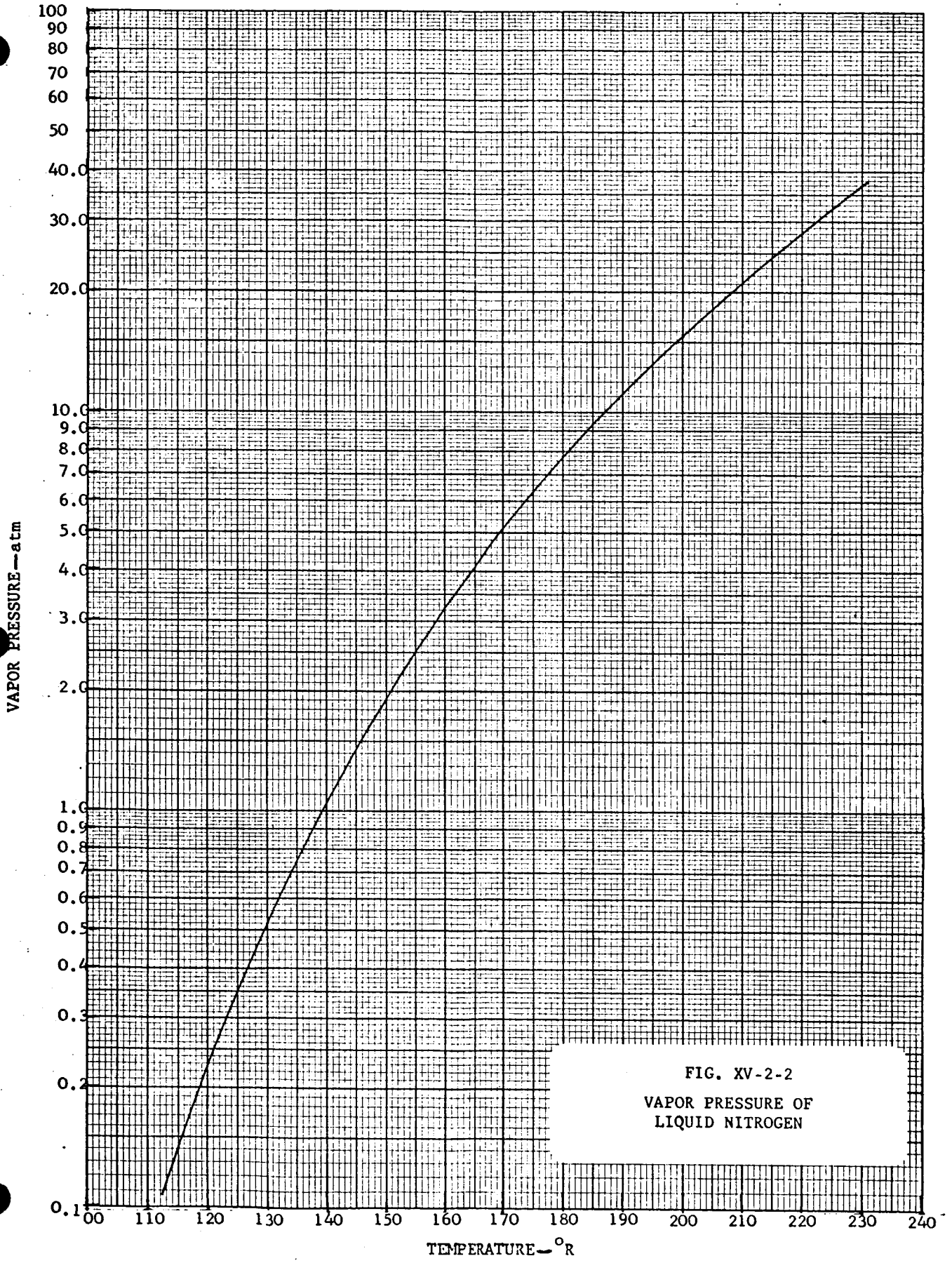
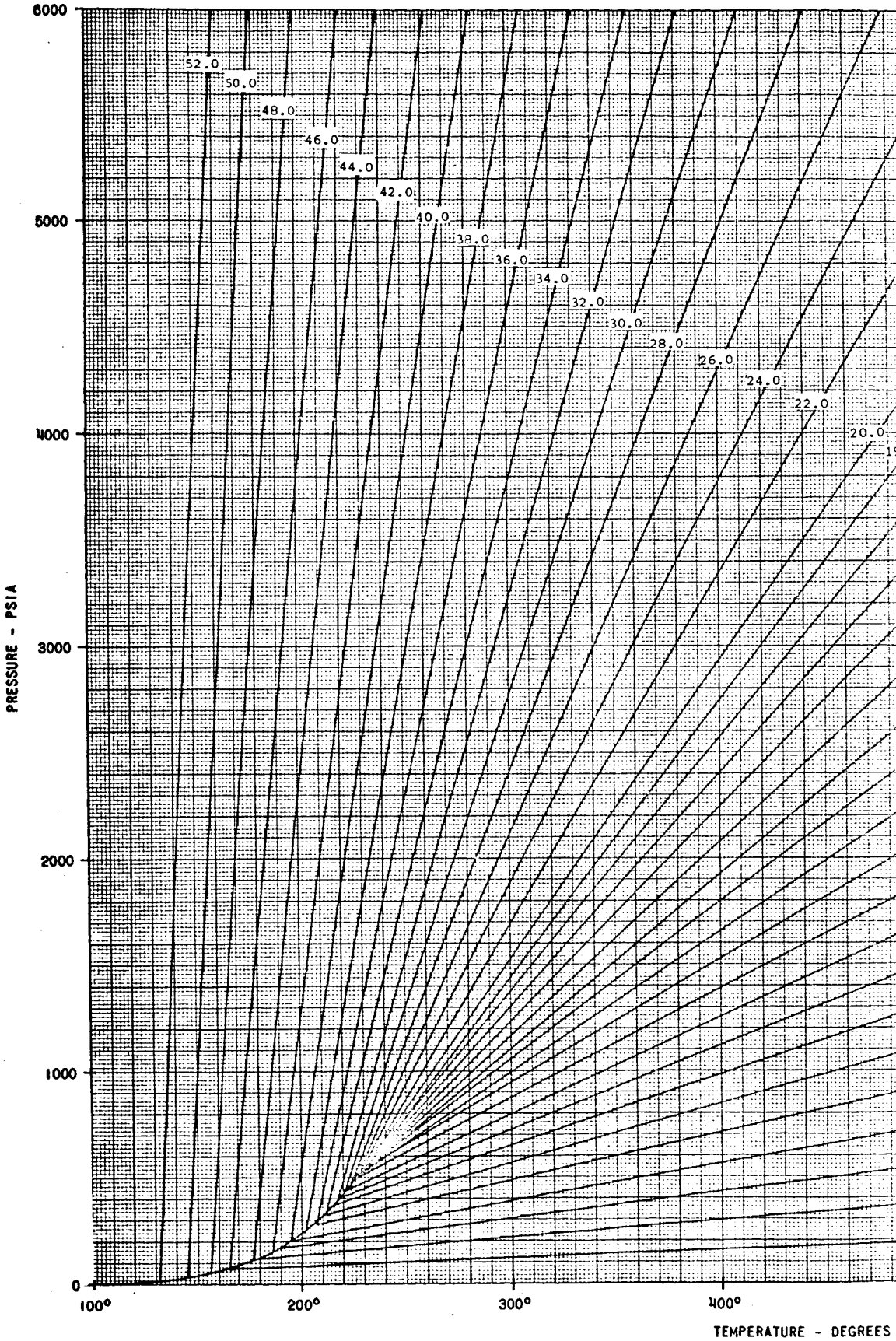


FIG. XV-2-2

VAPOR PRESSURE OF LIQUID NITROGEN


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
100°
200°
300°
400°
TEMPERATURE - DEGREES
52.0
50.0
48.0
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0

XV-2.13

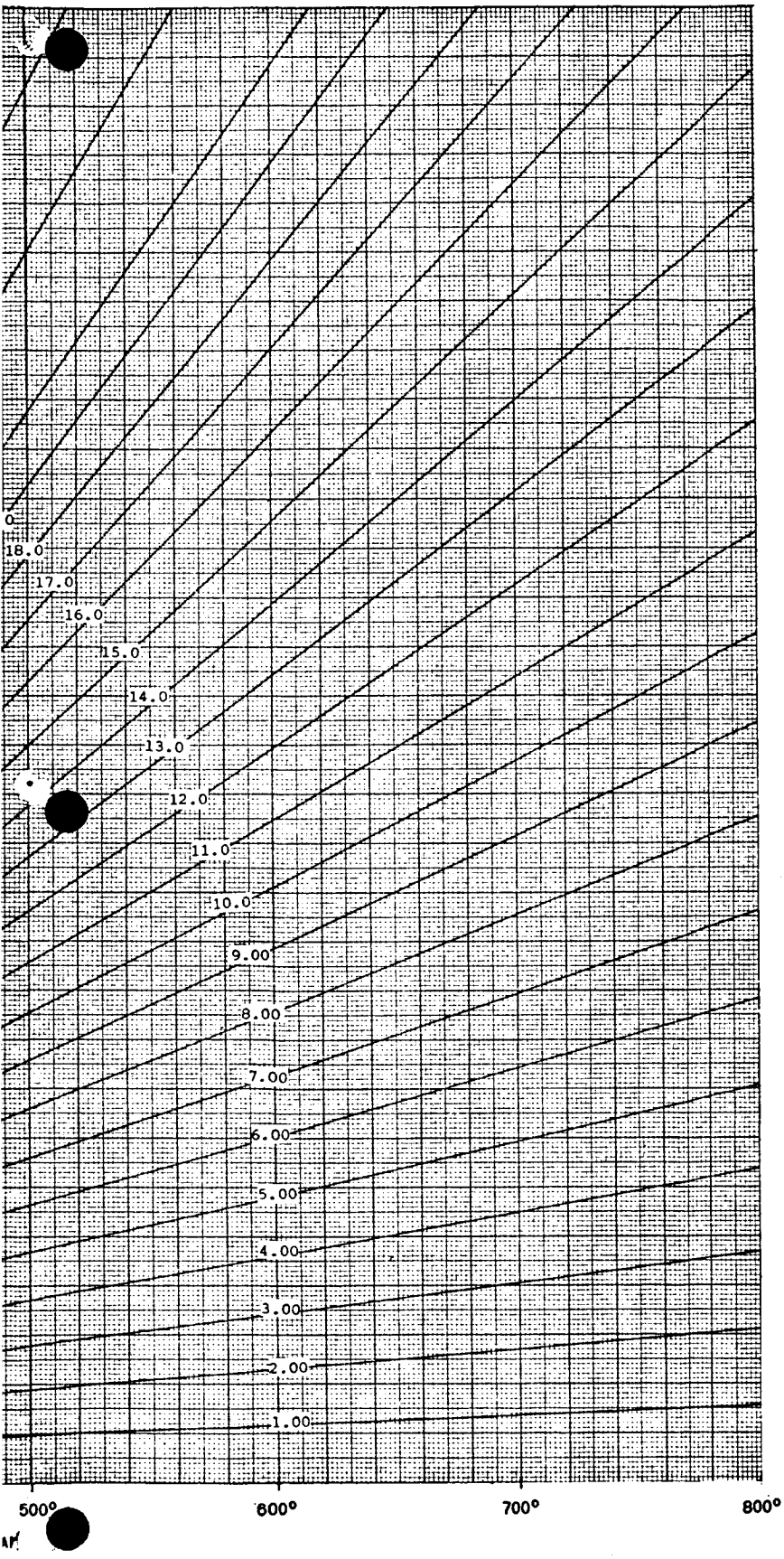


FIG. XV-2-3
NITROGEN (N_2)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

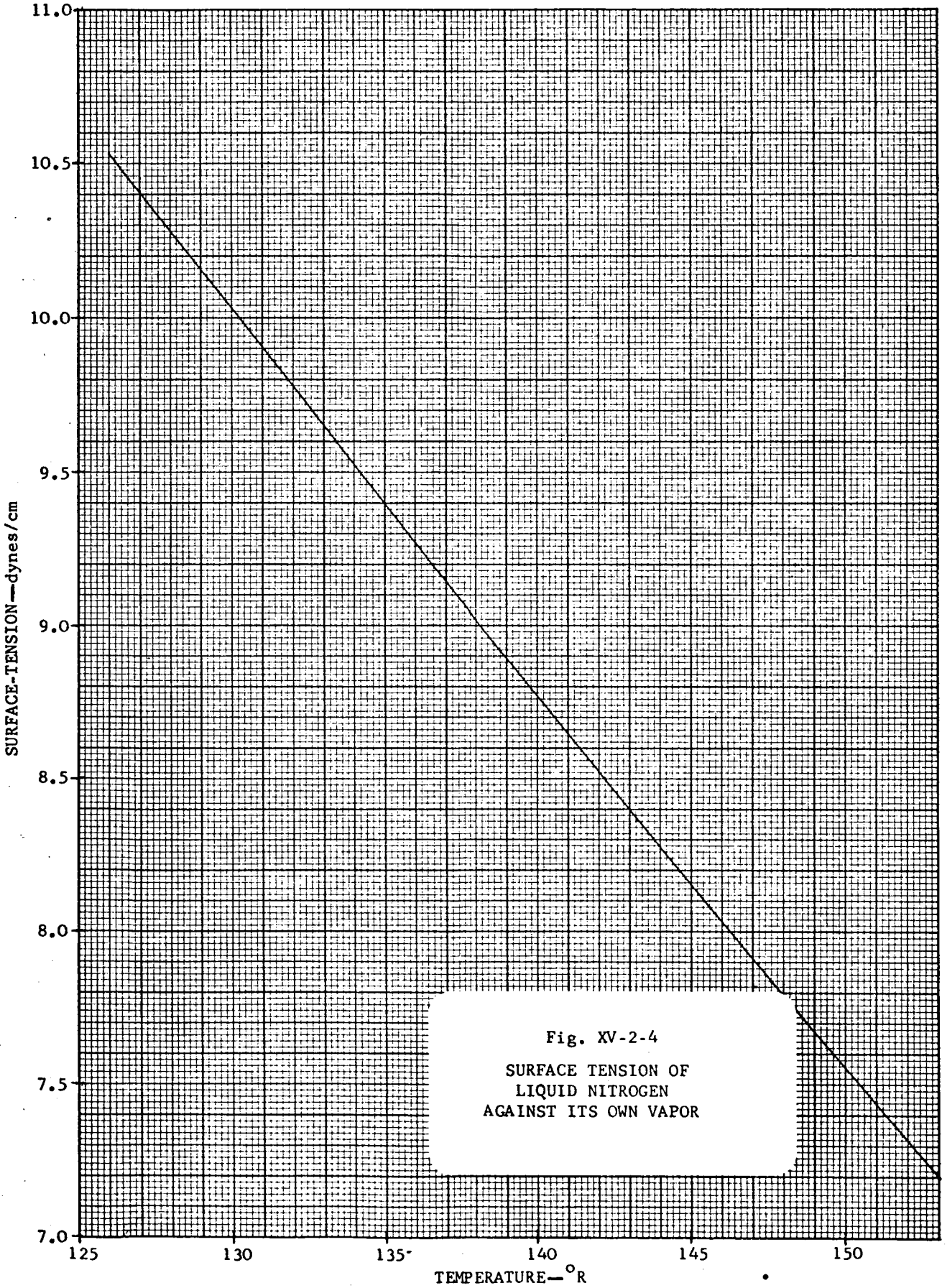


Fig. XV-2-4

SURFACE TENSION OF
LIQUID NITROGEN
AGAINST ITS OWN VAPOR

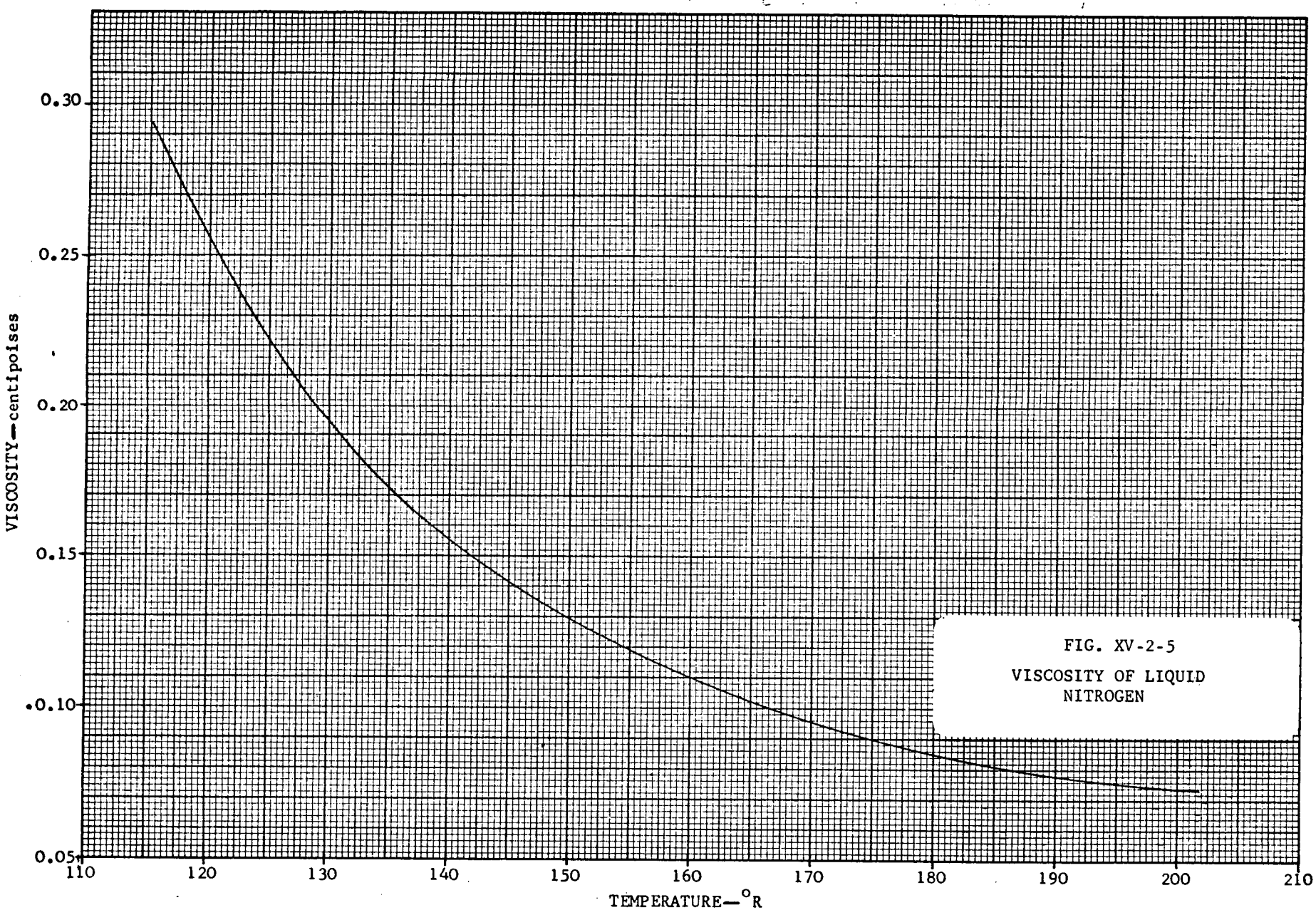


FIG. XV-2-5

VISCOSITY OF LIQUID NITROGEN

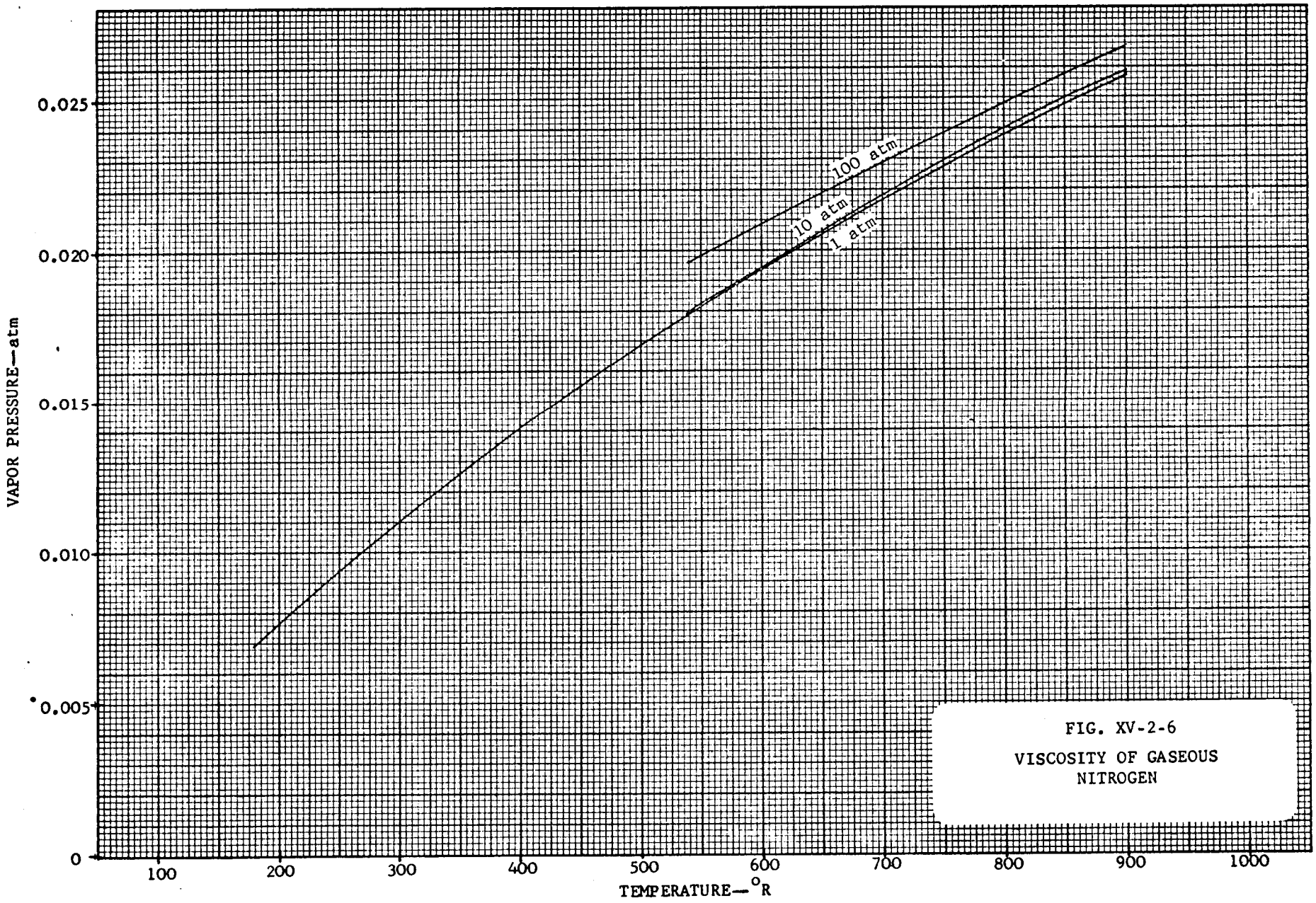


FIG. XV-2-6

VISCOSITY OF GASEOUS NITROGEN

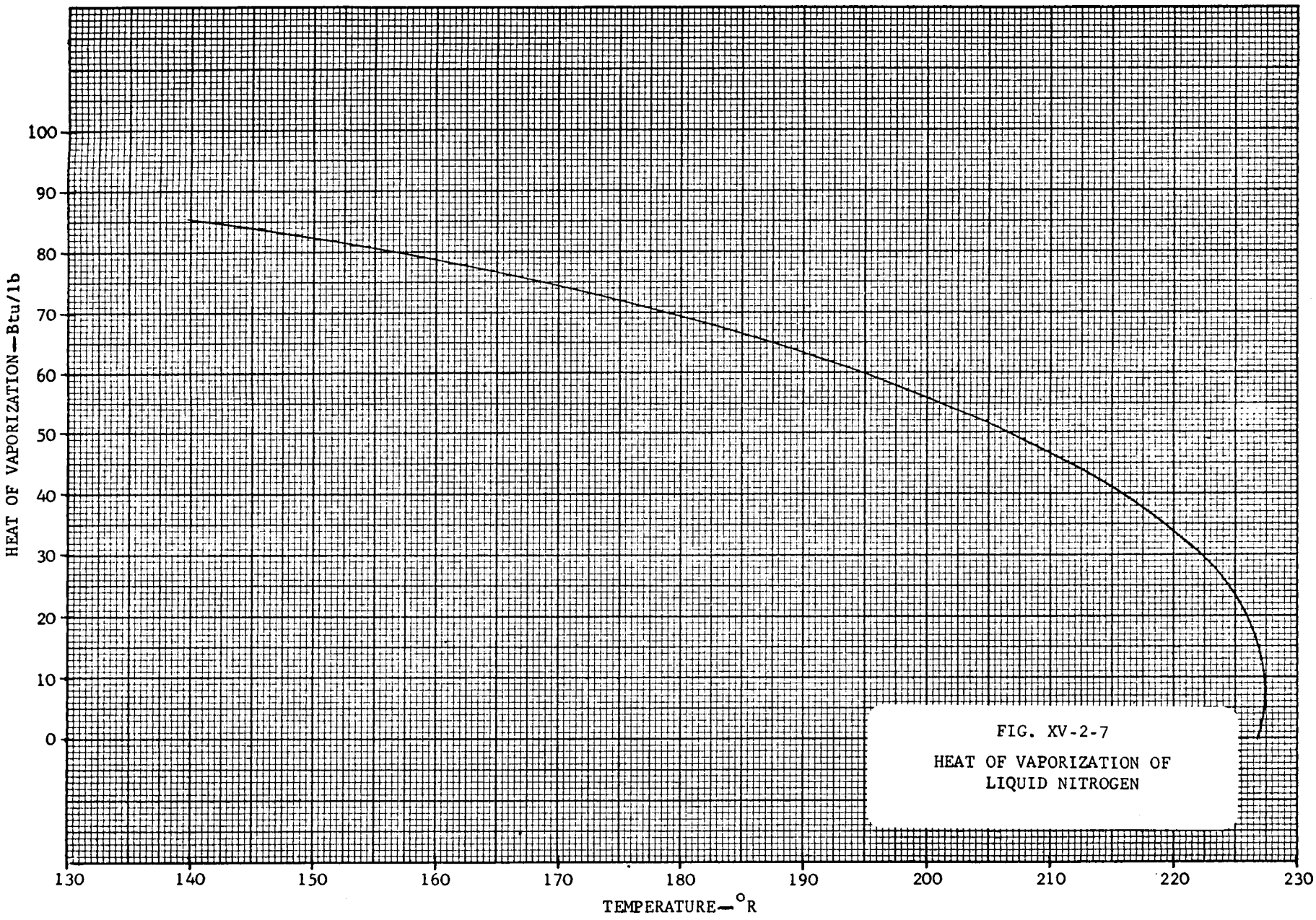


FIG. XV-2-7

HEAT OF VAPORIZATION OF LIQUID NITROGEN

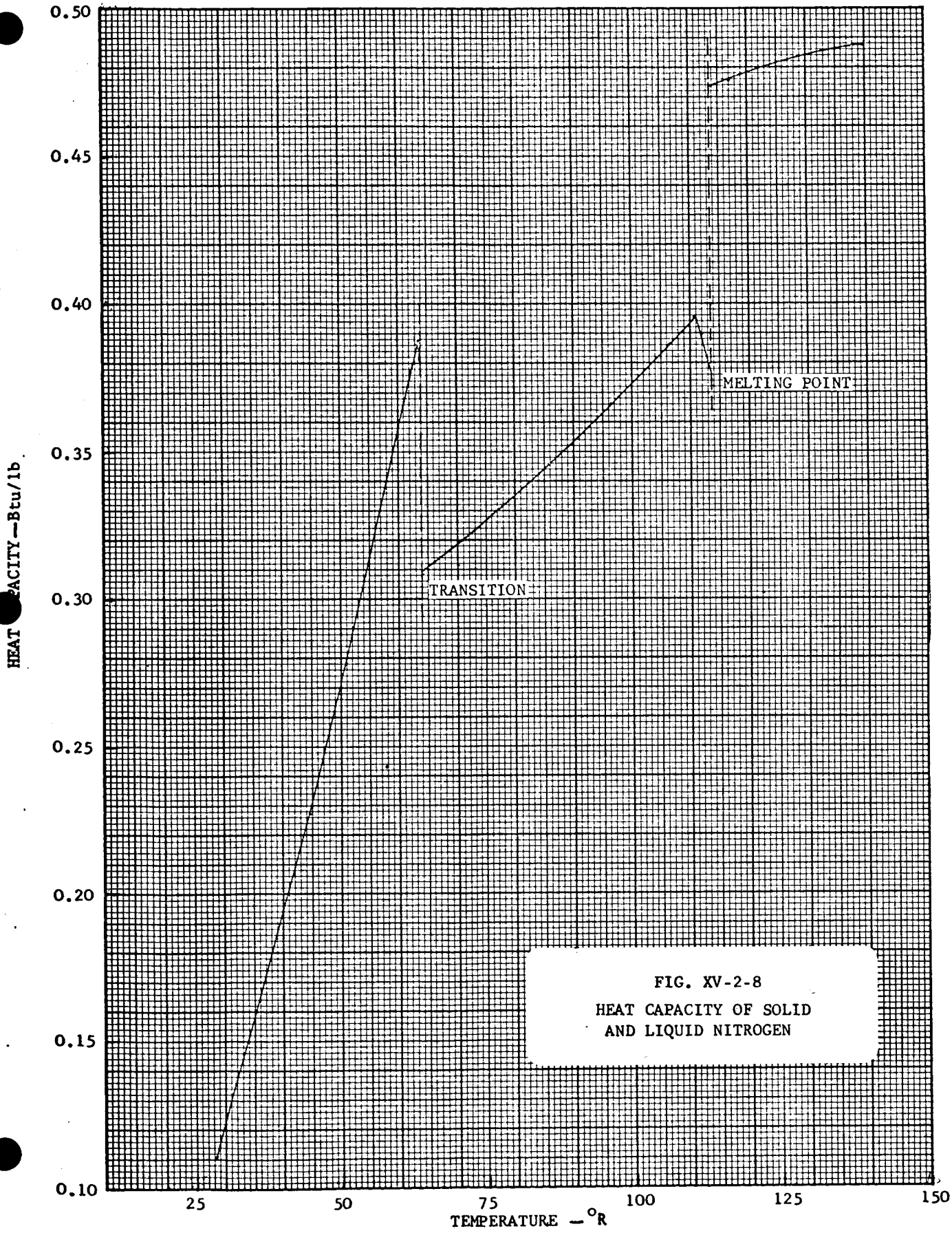


FIG. XV-2-8

HEAT CAPACITY OF SOLID AND LIQUID NITROGEN

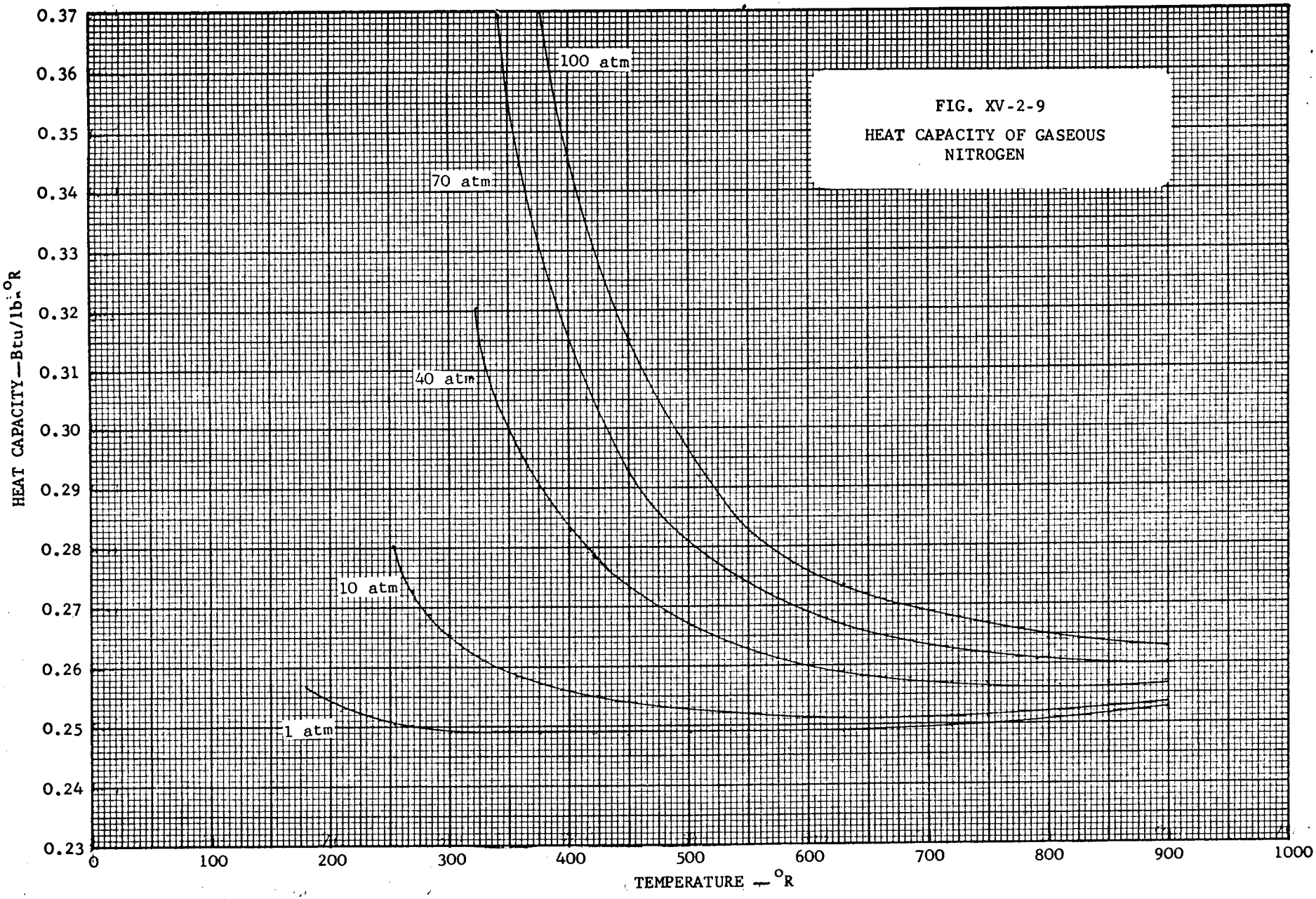


FIG. XV-2-9

HEAT CAPACITY OF GASEOUS NITROGEN

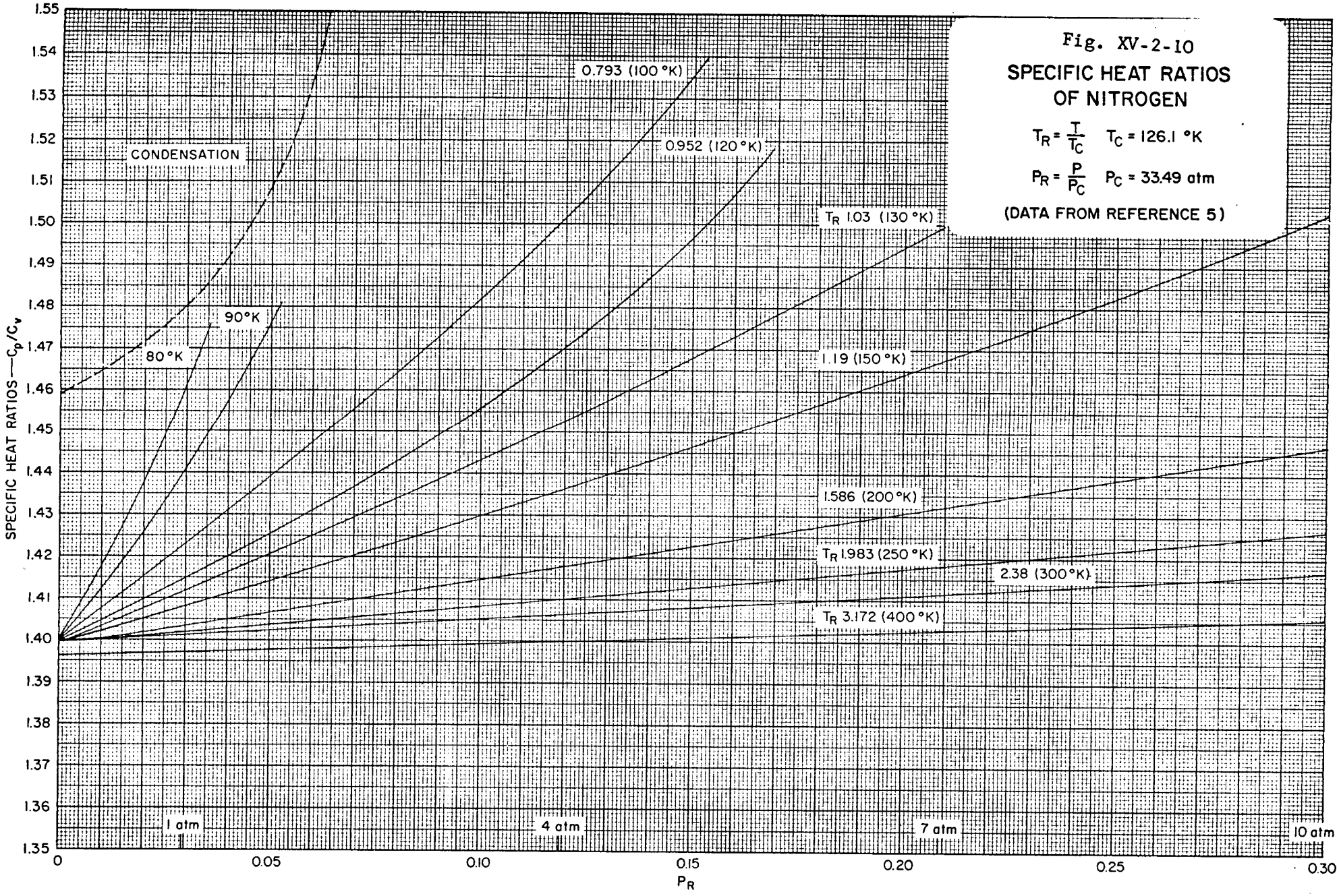


Fig. XV-2-10
SPECIFIC HEAT RATIOS OF NITROGEN
$T_R = \frac{T}{T_C}$ T_C = 126.1 °K
$P_R = \frac{P}{P_C}$ P_C = 33.49 atm
(DATA FROM REFERENCE 5)
CONDENSATION
80 °K
90 °K
0.793 (100 °K)
0.952 (120 °K)
T_R 1.03 (130 °K)
1.19 (150 °K)
1.586 (200 °K)
T_R 1.983 (250 °K)
2.38 (300 °K)
T_R 3.172 (400 °K)
1 atm
4 atm
7 atm
10 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.55
1.54
1.53
1.52
1.51
1.50
1.49
1.48
1.47
1.46
1.45
1.44
1.43
1.42
1.41
1.40
1.39
1.38
1.37
1.36
1.35
0
0.05
0.10
0.15
0.20
0.25
0.30

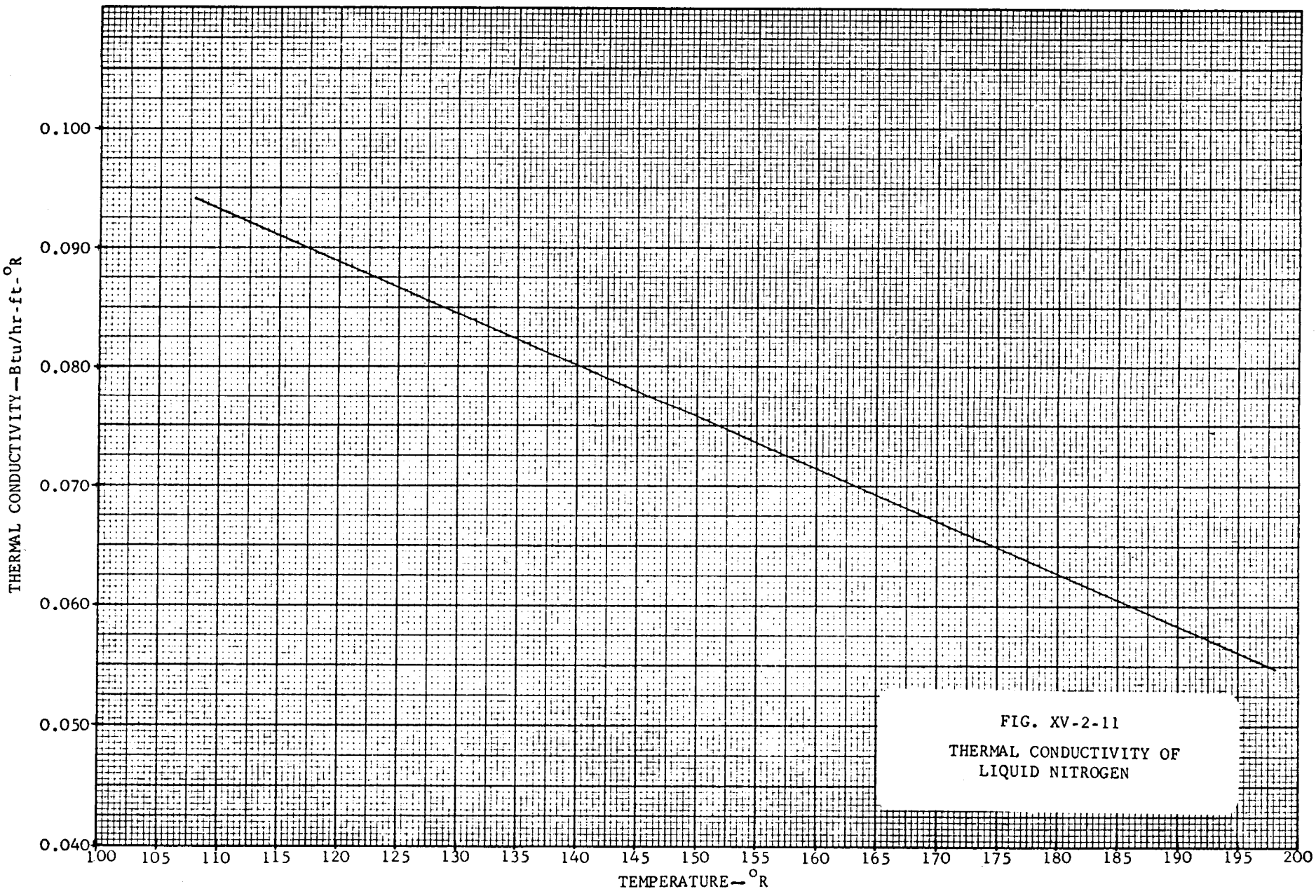


FIG. XV-2-11

THERMAL CONDUCTIVITY OF LIQUID NITROGEN

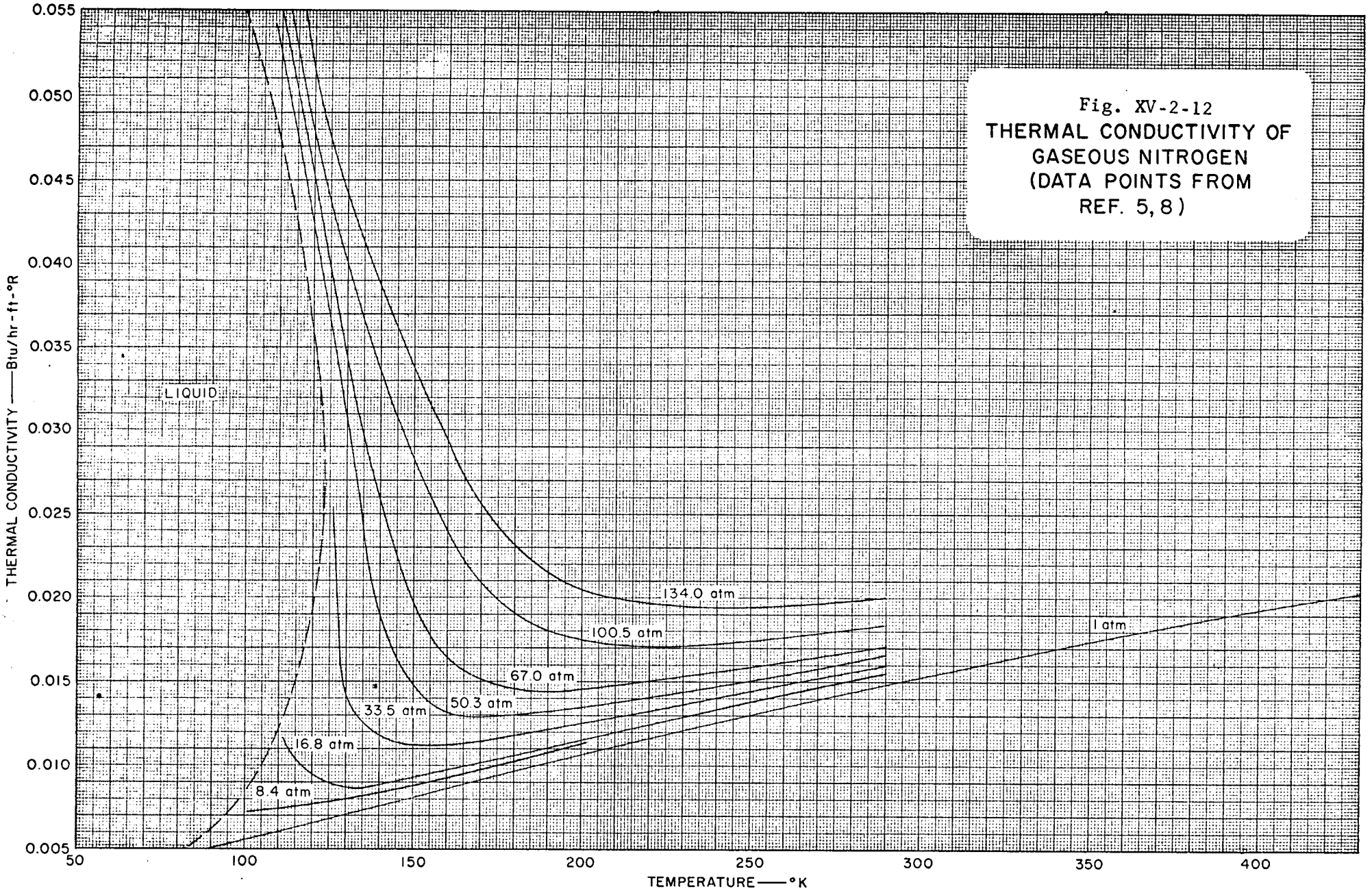


Fig. XV-2-12
THERMAL CONDUCTIVITY OF GASEOUS NITROGEN (DATA POINTS FROM REF. 5, 8)

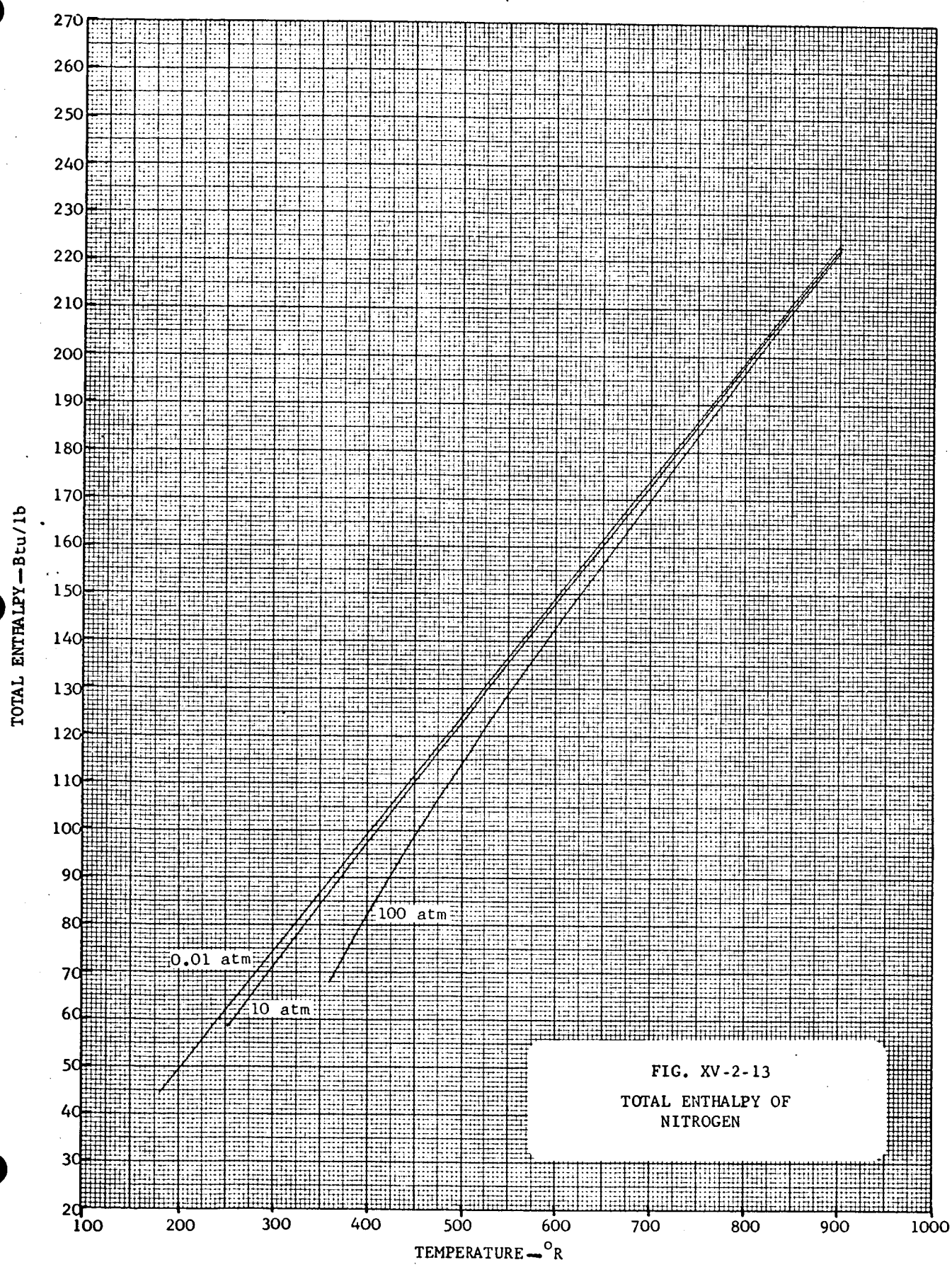


FIG. XV-2-13

TOTAL ENTHALPY OF NITROGEN

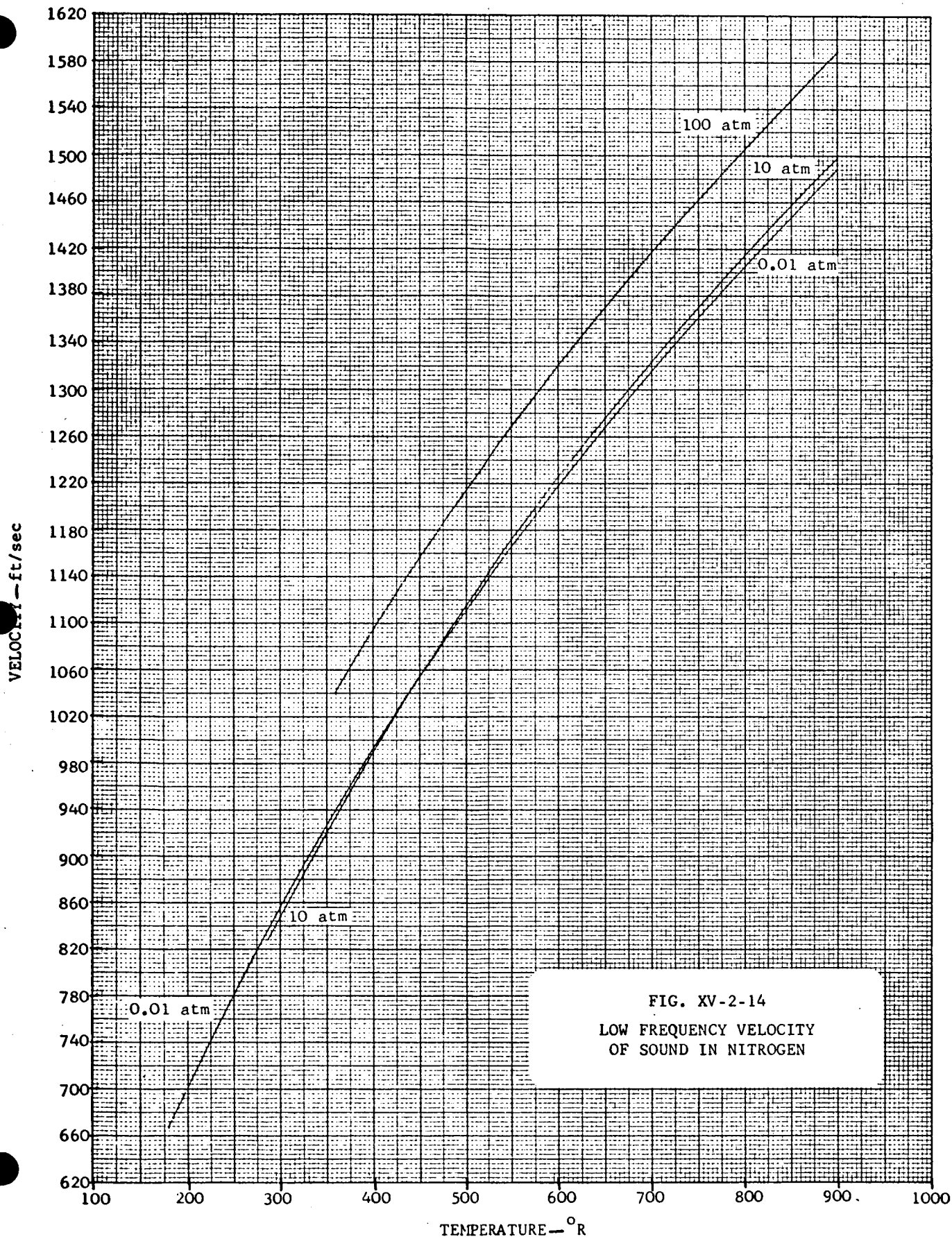


FIG. XV-2-14

LOW FREQUENCY VELOCITY OF SOUND IN NITROGEN

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Table XV-3-1

PHYSICAL CONSTANTS

OF

HYDROGEN*

		REF.
Molecular Weight	2.016	7
Boiling Point @ 1 atm.	-423.0°F	7
Freezing Point @ 1 atm.	-430.85°F	7
Specific Volume @ 70°F, 1 atm.	193 cu ft/lb	7
Vapor Pressure @ 20°K	13.07 psia	6
Specific Gravity, (Air = 1)	0.06952	7
Density		
Liquid @ -421.6°F	4.4 lb/cu ft	9
Gas @ 32°F, 1 atm.	0.005611 lb/cu ft	7
Critical Temperature	-399.8°F	7
Critical Pressure	188.2 psia	7
Critical Density	1.935 lb/cu ft	7
Latent Heat of Vaporization @ b.p.	192.86 Btu/lb	7
Latent Heat of Fusion @ m.p.	25.0 Btu/lb	7
Specific Heat of Gas		
c_p @ 60°F	3.39 Btu/lb-°F	7
c_v @ 60°F	2.40 Btu/lb-°F	7
Specific Heat Ratio, c_p/c_v @ 60°F	1.410	7
Thermal Conductivity @ 32°F	0.100 Btu/hr-ft-°F	7
Viscosity		
Liquid @ 20°K	9.33×10^{-6} lb/ft-sec	2
Gas @ 68°F, 1 atm.	6.25×10^{-5} lb/ft-sec	2
Solubility in Water @ 60°F	0.019 volume/volume H_2O	7
Surface Tension @ -427°F	1.58×10^{-4} lb/ft	9

*Normal Hydrogen: 75% ortho, 25% para
Equilibrium Hydrogen: 0.21% ortho, 99.19% para (at 20.4°K)

Table XV-3-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR MOLECULAR HYDROGEN
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	40.7027	42.0551	30934.1	598.169
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.651989	0.673653	495.512	9.58163
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	22.6126	23.3639	17185.6	332.316
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.362216	0.374252	275.284	5.32313
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-3-2

VAPOR PRESSURE OF LIQUIFIED
NORMAL HYDROGEN (Ref. 6)

TEMPERATURE		VAPOR PRESSURE	
°K	°R	psia	atm
14.00	25.20	1.070	0.0728
16.00	28.80	2.965	0.2018
18.00	32.40	6.688	0.4551
20.00	36.00	13.07	0.8891
22.00	39.60	22.99	1.564
24.00	43.20	37.41	2.545
26.00	46.80	57.29	3.899
28.00	50.40	83.69	5.695
30.00	54.00	117.7	8.010
32.00	57.60	160.5	10.923
33.00	59.40	185.6	12.632

(See Figure XV-3-1)

Table XV-3-3

VAPOR PRESSURE OF
SOLID NORMAL HYDROGEN
(Ref. 6)

TEMPERATURE		VAPOR PRESSURE	
°K	°R	psia	atm
10.0	18.0	0.0329	0.00224
11.0	19.8	0.0967	0.00658
12.0	21.6	0.2456	0.0167
13.0	23.4	0.5395	0.0367
13.81	24.8	0.9494	0.0646

(See Figure XV-3-2)

Table XV-3-4

DENSITY OF LIQUEFIED
NORMAL HYDROGEN (Ref. 6)

TEMPERATURE		DENSITY
°K	°R	lb/ft^3
13.95	25.11	4.821
14.0	25.2	4.819
16.0	28.8	4.710
18.0	32.4	4.589
20.0	36.0	4.458
22.0	39.6	4.305
24.0	43.2	4.133
26.0	46.8	3.934
28.0	50.4	3.695
30.0	54.0	3.389
32.0	57.6	2.913
33.18	59.72	1.880

Table XV-3-5

DENSITY OF SATURATED
VAPOR OF LIQUEFIED
NORMAL HYDROGEN
(Ref. 6)

TEMPERATURE		DENSITY
°K	°R	lb/ft^3
14.0	25.2	0.00311
16.0	28.8	0.0200
18.0	32.4	0.0411
20.0	36.0	0.0747
22.0	39.6	0.1248
24.0	43.2	0.1965
26.0	46.8	0.2975
28.0	50.4	0.4408
30.0	54.0	0.6528
32.0	57.6	1.015
33.2	59.7	1.88

Table XV-3-6

DENSITY OF NORMAL HYDROGEN (Ref. 6, 8, 10)

DENSITY-lb/ft^3							
PRESSURE / TEMP. psia / °R	500	1000	2000	3000	4000	5000	6000
50	4.18	4.42	4.82	5.09	5.28	-	-
100	1.14	2.27	3.43	3.99	4.33	4.61	4.85
150	0.62	1.27	2.29	2.98	3.43	3.80	4.12
200	0.45	0.90	1.68	2.29	2.78	3.17	3.50
300	0.305	0.595	1.128	1.584	1.973	2.309	2.655
400	0.228	0.452	0.861	1.223	1.550	1.835	2.100
500	0.184	0.364	0.687	1.000	1.276	1.528	1.750
600	0.153	0.302	0.572	0.844	1.087	1.313	1.517
700	0.132	0.260	0.505	0.729	0.947	1.145	1.331
800	0.116	0.226	0.450	0.645	0.834	1.019	1.185

(See Figure XV-3-3)

Table XV-3-7

SURFACE TENSION OF LIQUIFIED NORMAL HYDROGEN (Ref. 1)

TEMPERATURE		SURFACE TENSION
°K	°R	dynes/cm
13.0	23.5	3.49
15.0	27.0	3.13
20.0	36.0	2.23
25.0	45.0	1.33

(See Figure XV-3-4)

Table XV-3-8

VISCOSITY OF LIQUEFIED NORMAL HYDROGEN (Ref. 6)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises
14.4	25.92	0.0230
15.0	27.0	0.0218
16.0	28.8	0.0197
17.0	30.6	0.0178
18.0	32.4	0.0161
19.0	34.2	0.0146
20.0	36.0	0.0135
21.0	37.8	0.0126

(See Figure XV-3-5)

Table XV-3-9

VISCOSITY OF SATURATED GASEOUS NORMAL HYDROGEN (Ref. 6)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	micropoises
14.0	25.2	10.87
16.0	28.8	10.88
18.0	32.4	10.90
20.0	36.0	10.93
22.0	39.6	10.98
24.0	43.2	11.05
26.0	46.8	11.17
28.0	50.4	11.41
30.0	54.0	11.56

(See Figure XV-3-6)

Table XV-3-10

HEAT OF VAPORIZATION OF LIQUEFIED NORMAL HYDROGEN (Ref. 4)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
15.0	27.0	195.5	26.2	47.16	169.73
17.8	32.04	192.05	27.3	49.14	160.20
19.7	35.46	190.79	28.3	50.94	151.20
20.5	36.90	189.89	30.0	54.00	128.09
22.0	39.60	185.93	31.3	56.34	102.77
23.0	41.40	183.59	32.6	58.68	59.40
24.75	44.55	176.39	33.18	59.72	0.0

(See Figure XV-3-7)

Table XV-3-11

HEAT CAPACITY OF LIQUEFIED NORMAL HYDROGEN AT SATURATION PRESSURE (Ref. 6)

TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb-°K
13.95	25.11	1.642
14.0	25.2	1.642
15.0	27.0	1.716
16.0	28.8	1.801
17.0	30.6	1.900
18.0	32.4	2.004
19.0	34.2	2.118
20.0	36.0	2.232

(See Figure XV-3-8)

Table XV-3-12

HEAT CAPACITY OF HYDROGEN GAS (Ref. 3)

TEMPERATURE		HEAT CAPACITY, C_p—Btu/lb-°R			
°K	°R	0 atm	1 atm	10 atm	100 atm
20	36	2.462			
30	54	2.462	2.589		
40	72	2.464	2.526	3.411	
60	108	2.481	2.506	2.738	3.898
80	144	2.552	2.566	2.682	3.511
100	180	2.673	2.681	2.748	3.246
120	216	2.814	2.819	2.862	3.193
140	252	2.948	2.951	2.981	3.215
160	288	3.062	3.065	3.088	3.276
180	324	3.156	3.158	3.177	3.327
200	360	3.231	3.233	3.247	3.362
220	396	3.290	3.291	3.305	3.402
240	432	3.336	3.337	3.348	3.434
260	468	3.373	3.374	3.382	3.451
280	504	3.398	3.400	3.406	3.463
300	540	3.417	3.418	3.424	3.473
320	576	3.431	3.432	3.437	3.479
340	612	3.442	3.443	3.447	3.483
360	648	3.449	3.450	3.454	3.486
380	684	3.454	3.456	3.458	3.486
400	720	3.458	3.459	3.462	3.486
420	756	3.461	3.462	3.463	3.486
440	792	3.462	3.463	3.465	3.485
460	828	3.463	3.464	3.466	3.485
480	864	3.465	3.465	3.467	3.484
500	900	3.466	3.466	3.468	3.483

(See Figure XV-3-9)

Table XV-3-13

THERMAL CONDUCTIVITY OF GASEOUS NORMAL HYDROGEN (Ref. 3, 5)

TEMPERATURE			REDUCED THERMAL CONDUCTIVITY, K_R													
°K	°R	T_R	Atm	1	1.30	2.60	5.19	7.79	10.40	12.98	25.96	64.9	130	260	650	1298
			P_R	0.077	0.1	0.2	0.4	0.6	0.8	1.0	2.0	5.0	10.0	20.0	50.0	100
20.00	36.00	0.60		0.245							1.80		2.00			
		0.70		0.270	0.297						1.76		2.00			
26.54	47.77	0.80		0.310	0.330	0.390					1.70		1.98	2.10		
30.00	54.00	0.90		0.345	0.365	0.415	0.480	0.582			1.60	1.80	1.97	2.10		
33.18	59.72	1.00		0.375	0.397	0.440	0.495	0.560	0.635	1.00	1.50	1.78	1.95	2.09	2.45	2.71
49.70	89.46	1.50		0.545	0.56	0.580	0.608	0.623	0.682	0.712	0.881	1.45	1.77	2.05	2.50	2.92
66.36	119.4	2.00		0.690		0.730	0.772	0.791	0.822	0.84	0.95	1.35	1.62	2.00	2.53	3.03
99.54	179.2	3.00		1.000						1.18		1.43	1.66	1.93	2.55	3.11
132.7	238.9	4.00		1.31						1.50		1.60	1.80	2.07	2.61	3.15
165.9	298.6	5.00		1.60						1.78			2.00	2.25	2.76	3.27
199.1	358.3	6.00		1.90						2.05			2.24	2.45	2.93	3.42
232.3	418.1	7.00		2.18						2.32			2.50	2.70	3.10	3.62
265.4	477.8	8.00		2.45						2.55			2.75	2.95	3.30	3.81
298.6	587.5	9.00		2.73									3.03	3.20	3.50	4.01
331.8	597.2	10.00		3.00									3.30	3.50	3.71	

$$T_R = \frac{T}{T_c} \qquad T_c = 33.18\ ^\circ K$$

$$P_R = \frac{P}{P_c} \qquad P_c = 12.98\ \text{atm}$$

$$K_R = \frac{K}{K_c} \qquad K_c = 15.9 \times 10^{-5}\ \text{cal/sec-cm-}^\circ K$$

(See Figure XV-3-11)

Table XV-3-14
THERMAL CONDUCTIVITY
OF LIQUEFIED NORMAL
AND PARA HYDROGEN
(Ref. 4)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
16	28.8	0.06270
17	30.6	0.06403
18	32.4	0.06542
19	34.2	0.06675
20	36.0	0.06813
21	37.8	0.06946
22	39.6	0.07079
23	41.4	0.07212
24	43.2	0.07351
25	45.0	0.07484
26	46.8	0.07617
27	48.6	0.07755
28	50.4	0.07888
29	52.2	0.08021
30	54.0	0.08160

(See Figure XV-3-12)

Table XV-3-15

TOTAL ENTHALPY OF HYDROGEN (Ref. 3)

TEMPERATURE		TOTAL ENTHALPY—Btu/lb			
°K	°R	0.01 atm	1.0 atm	10 atm	100 atm
60	108	492.82	491.22	476.3	378.7
80	144	583.25	582.23	573.32	512.29
100	180	677.16	676.53	670.91	632.50
120	216	775.92	775.53	771.85	748.26
140	252	879.71	879.47	877.05	863.34
160	288	987.96	987.77	986.37	980.02
180	324	1099.9	1099.8	1099.2	1099.0
200	360	1215.2	1214.9	1214.9	1219.5
220	396	1332.4	1332.4	1332.9	1341.2
240	432	1451.7	1451.8	1452.7	1464.5
260	468	1572.5	1572.7	1573.9	1588.3
280	504	1694.4	1694.5	1696.0	1712.8
300	540	1817.1	1817.3	1819.0	1837.6
320	576	1940.4	1940.6	1942.5	1962.8
340	612	2064.1	2064.4	2066.4	2088.2
360	648	2188.2	2188.4	2190.6	2213.7
380	684	2312.4	2312.6	2315.0	2339.2
400	720	2436.8	2437.1	2439.5	2464.7
420	756	2561.4	2561.6	2564.2	2590.2
440	792	2685.9	2686.2	2688.9	2715.6
460	828	2810.6	2810.9	2813.6	2840.7
480	864	2935.3	2935.6	2938.5	2966.6
500	900	3060.1	3060.4	3063.3	3092.0

(See Figure XV-3-13)

Table XV-3-16

LOW FREQUENCY VELOCITY OF SOUND IN HYDROGEN (Ref. 3)

TEMPERATURE		VELOCITY — ft/sec			
°K	°R	0.0 atm	1.0 atm	10 atm	100 atm
20	36	1216.			
40	72	1720.	1710.	1631.	
60	108	2101.	2101.	2101.	3070.
80	144	2405.	2406.	2421.	3000.
100	180	2651.	2653.	2677.	3145.
120	216	2863.	2866.	2894.	3300.
140	252	3055.	3058.	3086.	3460.
160	288	3236.	3239.	3267.	3610.
180	324	3408.	3411.	3438.	3765.
200	360	3574.	3577.	3604.	3914.
220	396	3734.	3737.	3764.	4059.
240	432	3888.	3891.	3916.	4200.
260	468	4038.	4041.	4065.	4340.
280	504	4183.8	4186.	4212.	4477.
300	540	4325.8	4328.	4349.	4609.
320	576	4463.9	4469.	4493.	4742.
340	612	4598.4	4601.	4622.	4870.
360	648	4729.6	4733.	4750.	4994.
380	684	4857.3	4862.	4882.	5114.
400	720	4983.2	4986.	5006.	5234.
420	756	5105.3	5110.	5131.	5350.
440	792	5224.8	5226.	5246.	5466.
460	828	5341.9	5346.	5362.	5577.
480	864	5456.1	5457.	5478.	5685.
500	900	5568.7	5569.	5590.	5793.

(See Figure XV-3-14
Figure XV-3-15)

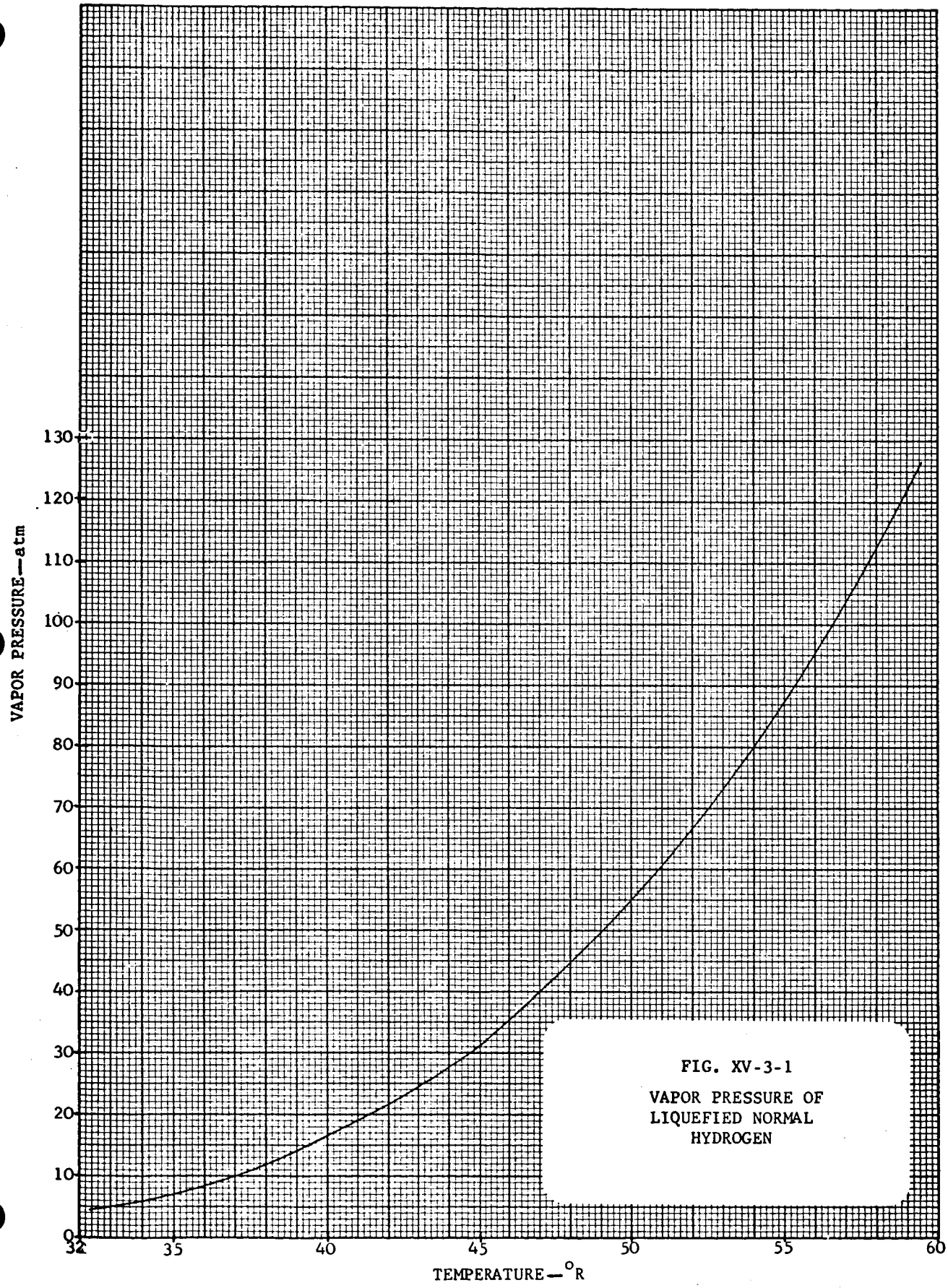


FIG. XV-3-1

VAPOR PRESSURE OF LIQUEFIED NORMAL HYDROGEN

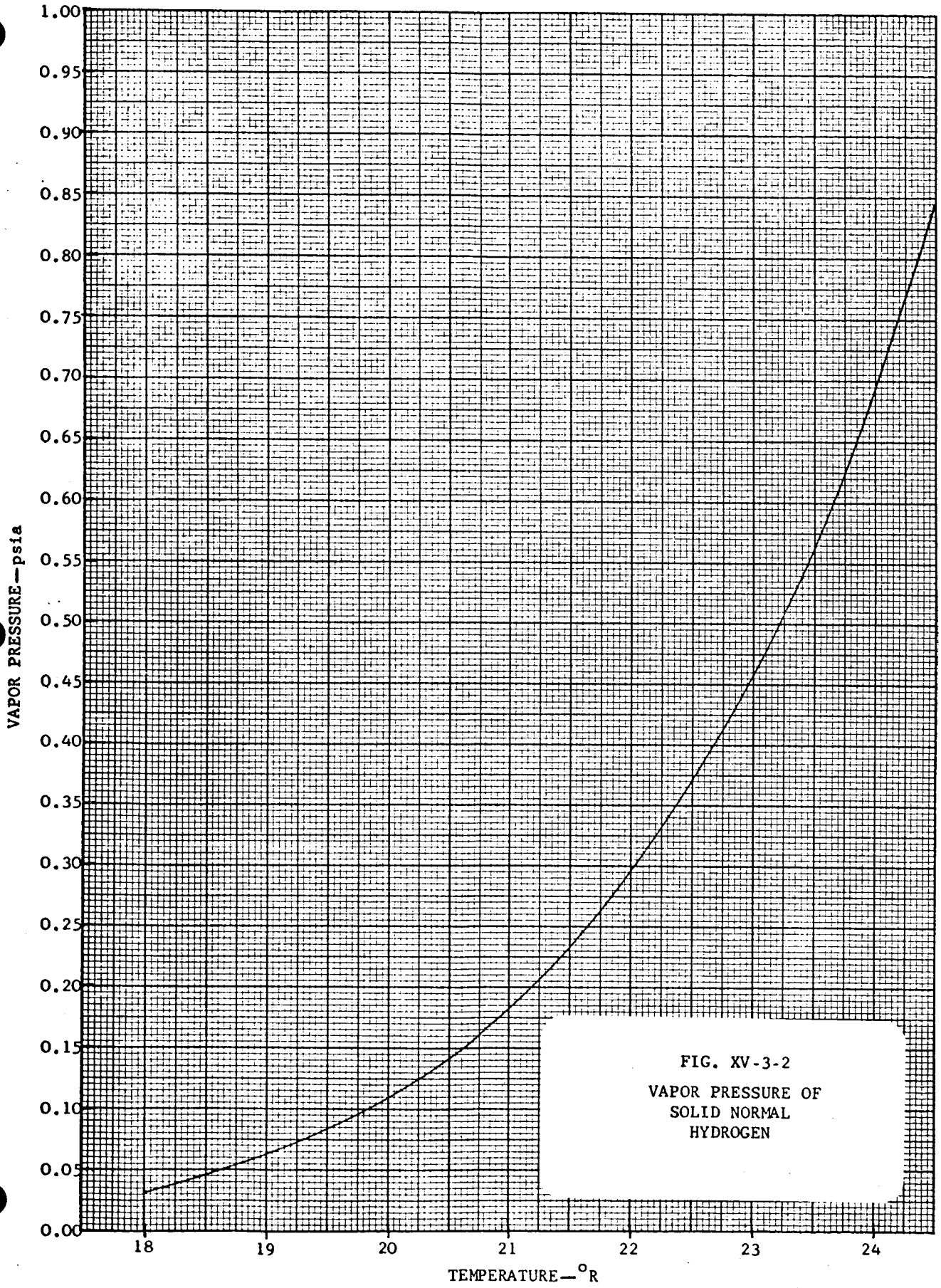
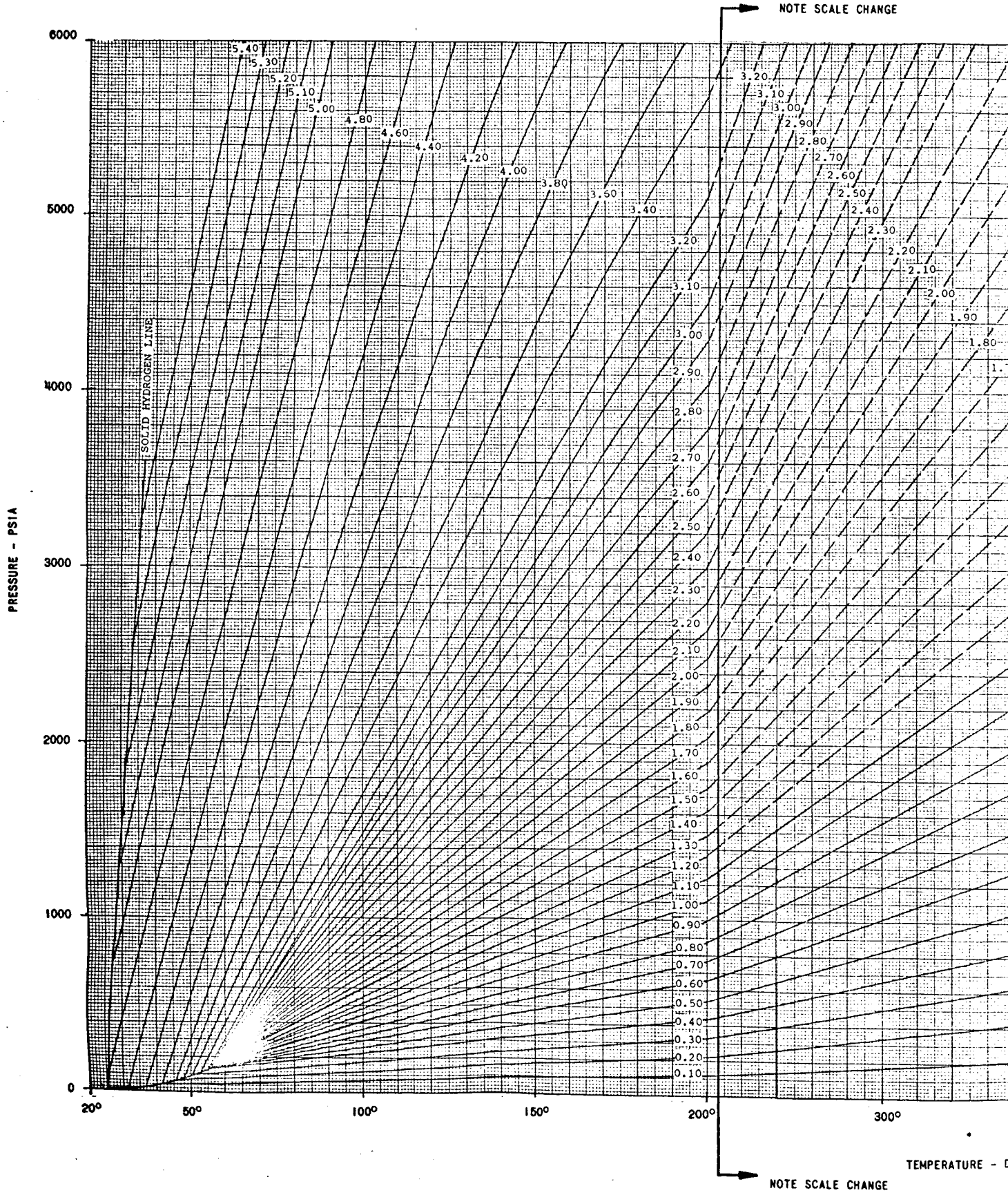


FIG. XV-3-2

VAPOR PRESSURE OF SOLID NORMAL HYDROGEN


NOTE SCALE CHANGE
PRESSURE - PSIA
6000
5000
4000
3000
2000
1000
0
SOLID HYDROGEN LINE
20°
50°
100°
150°
200°
300°
TEMPERATURE - D
NOTE SCALE CHANGE

XV-3-3-1

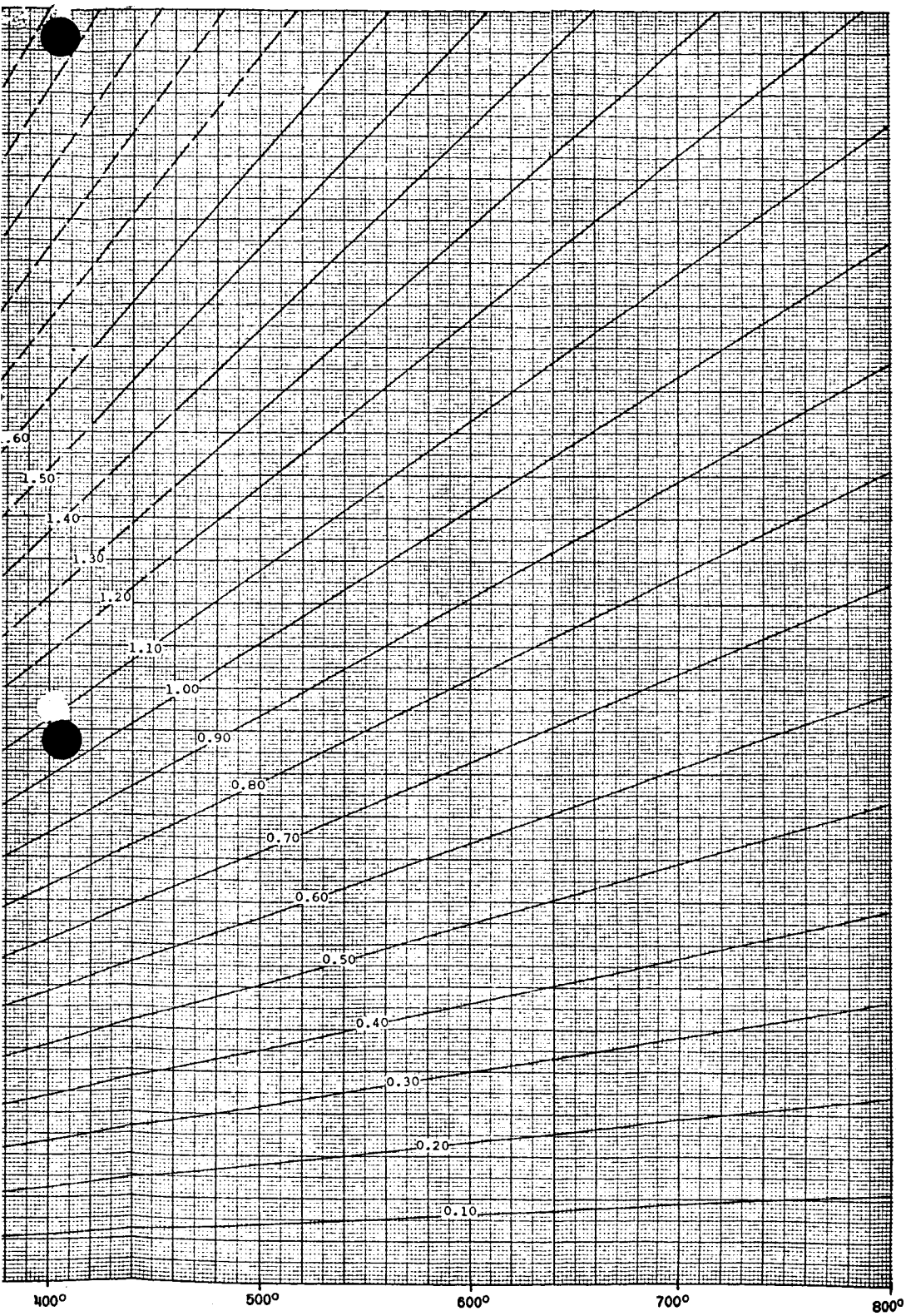


FIG. XV-3-3
HYDROGEN (H_2)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

COMMONLY ACCEPTED DATA

• EXTRAPOLATED OR UNCONFIRMED DATA

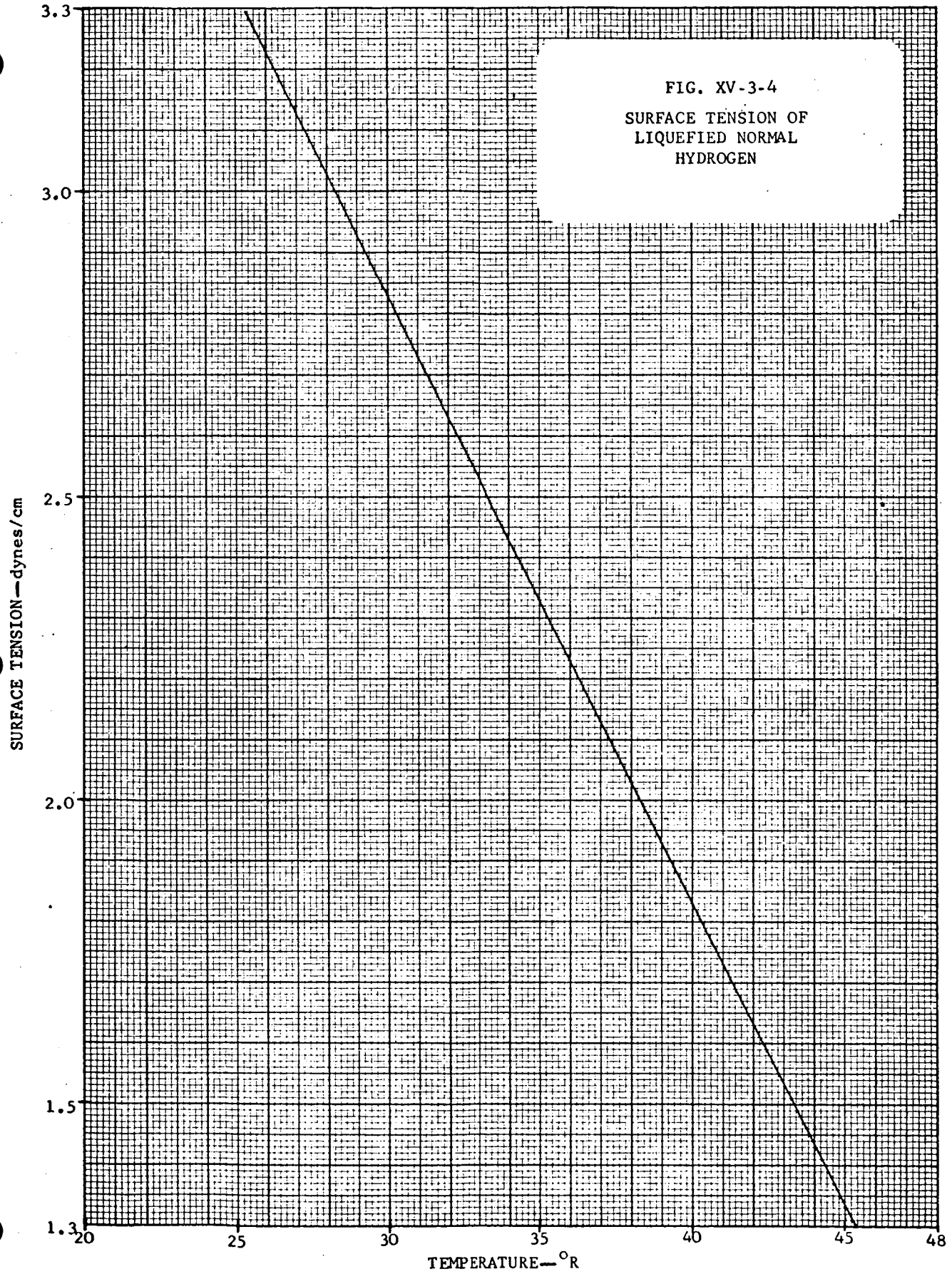


FIG. XV-3-4

SURFACE TENSION OF LIQUEFIED NORMAL HYDROGEN

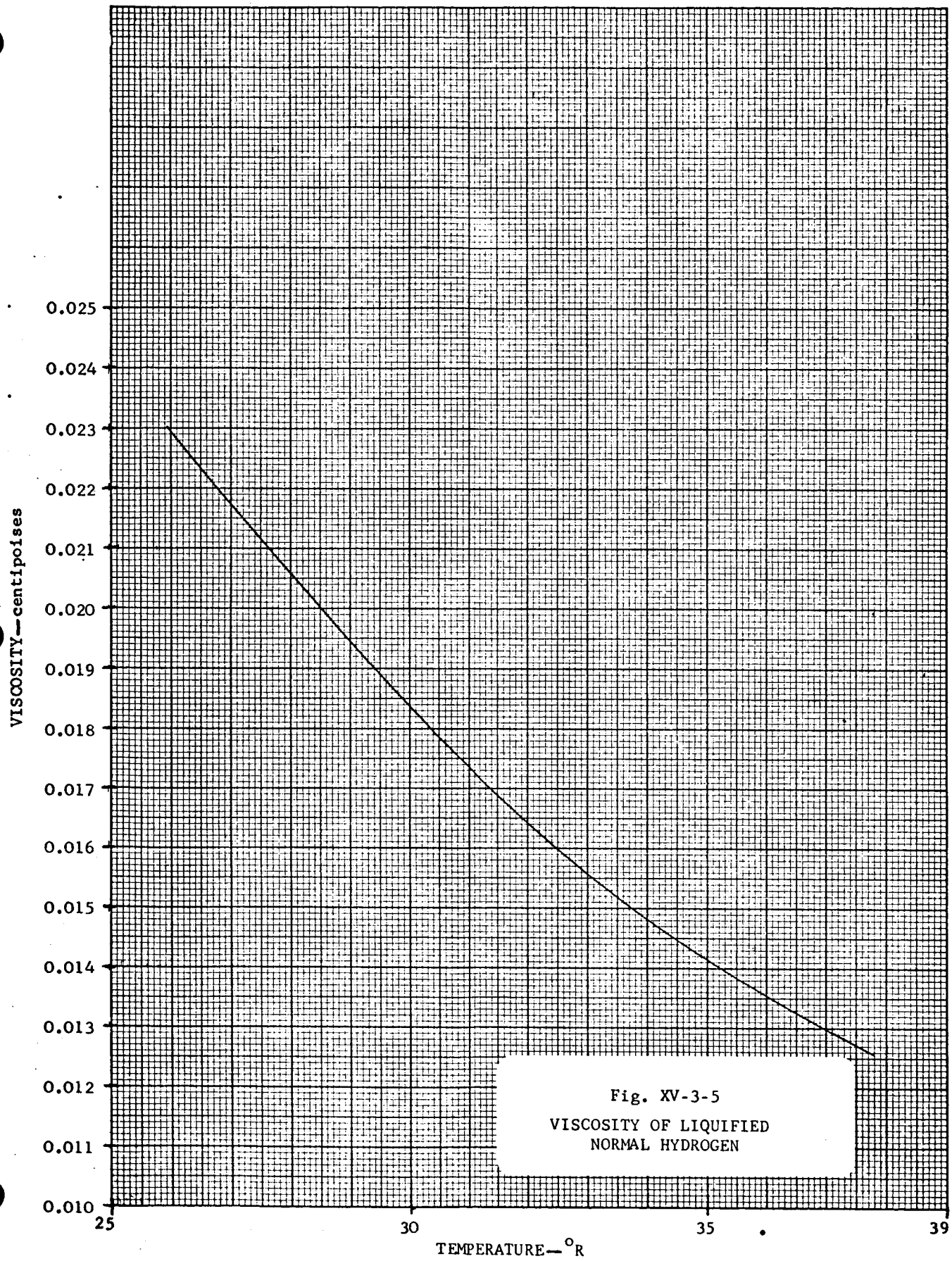


Fig. XV-3-5

VISCOSITY OF LIQUIFIED NORMAL HYDROGEN

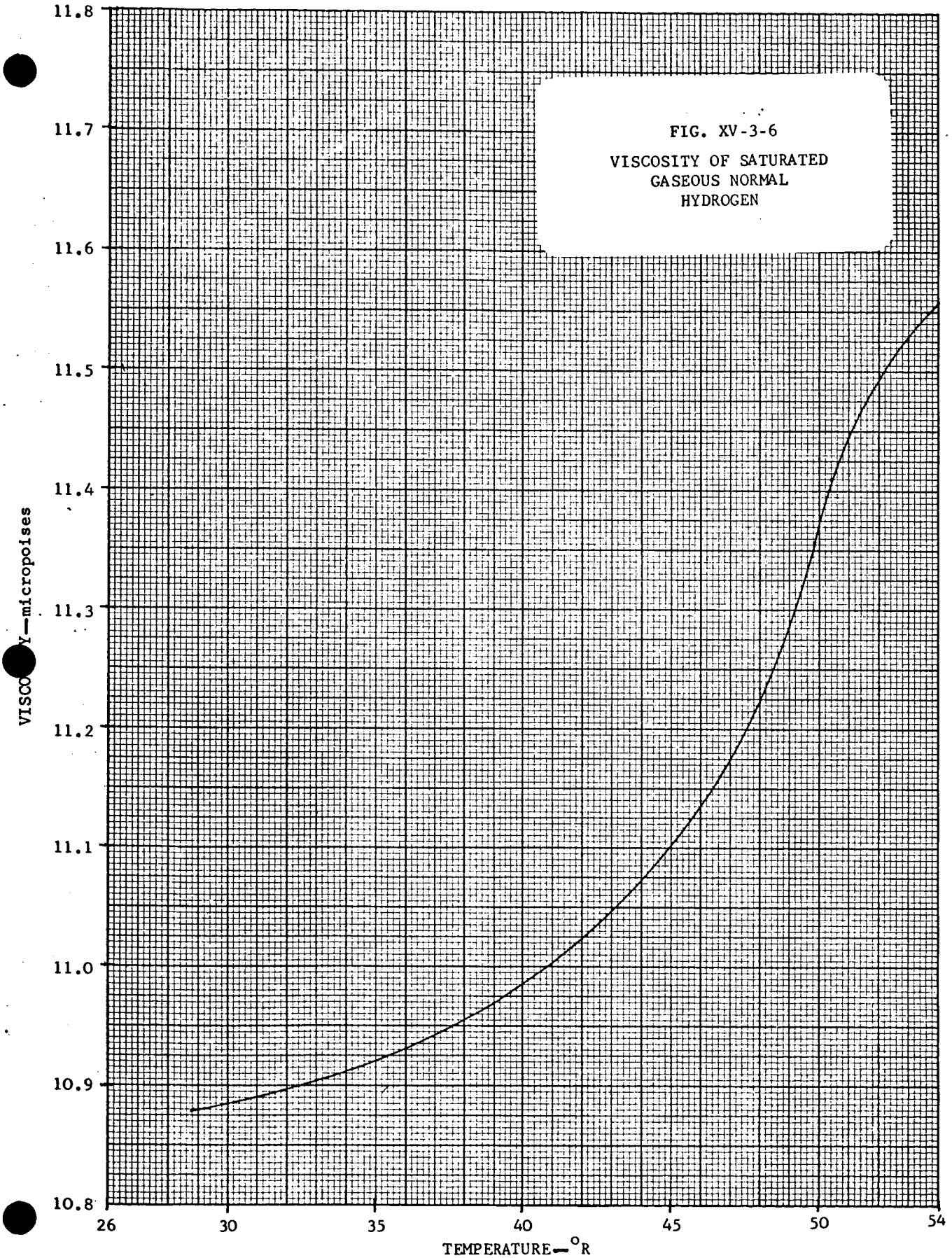


FIG. XV-3-6

VISCOSITY OF SATURATED GASEOUS NORMAL HYDROGEN

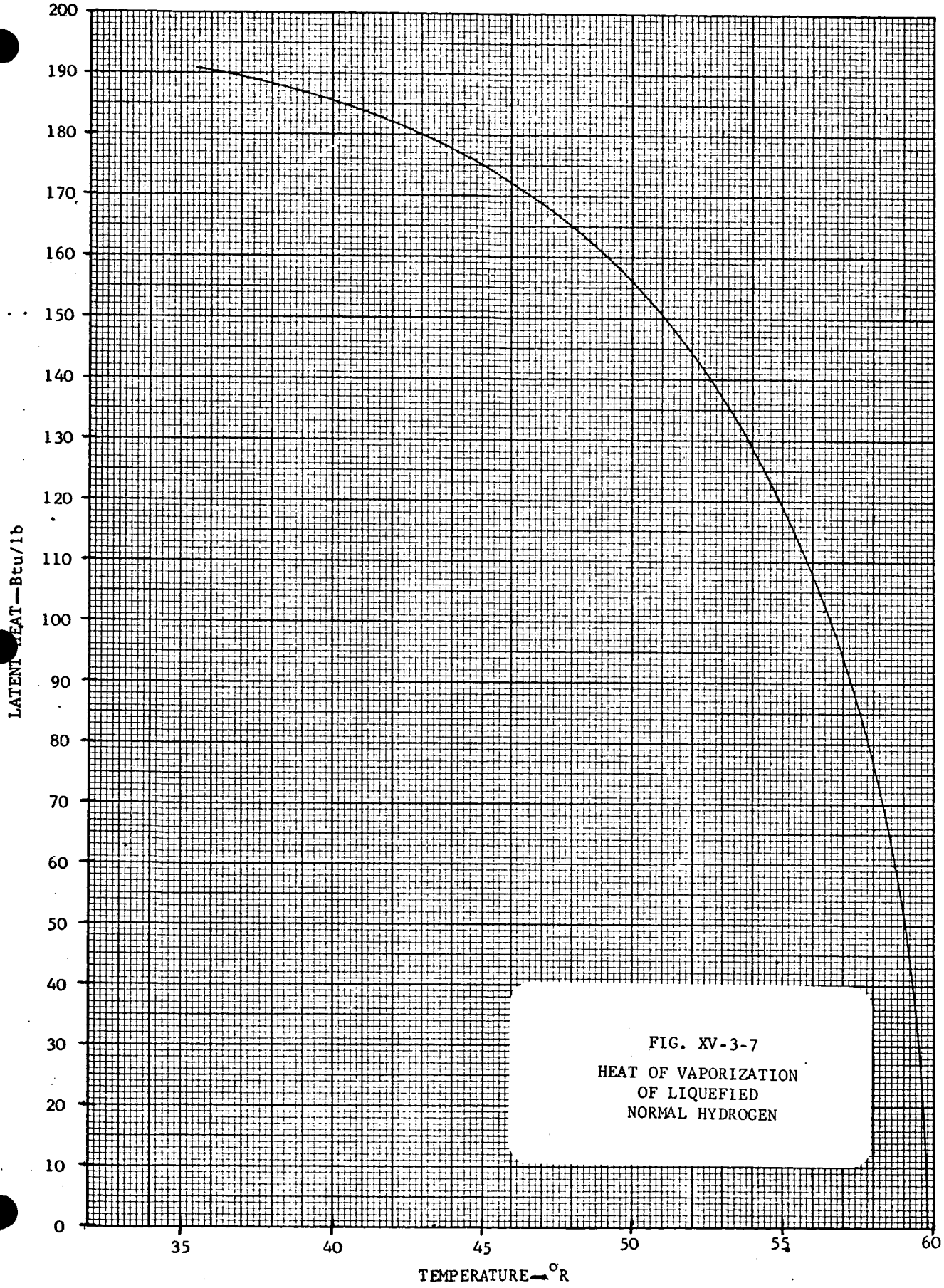


FIG. XV-3-7

HEAT OF VAPORIZATION
OF LIQUEFIED
NORMAL HYDROGEN

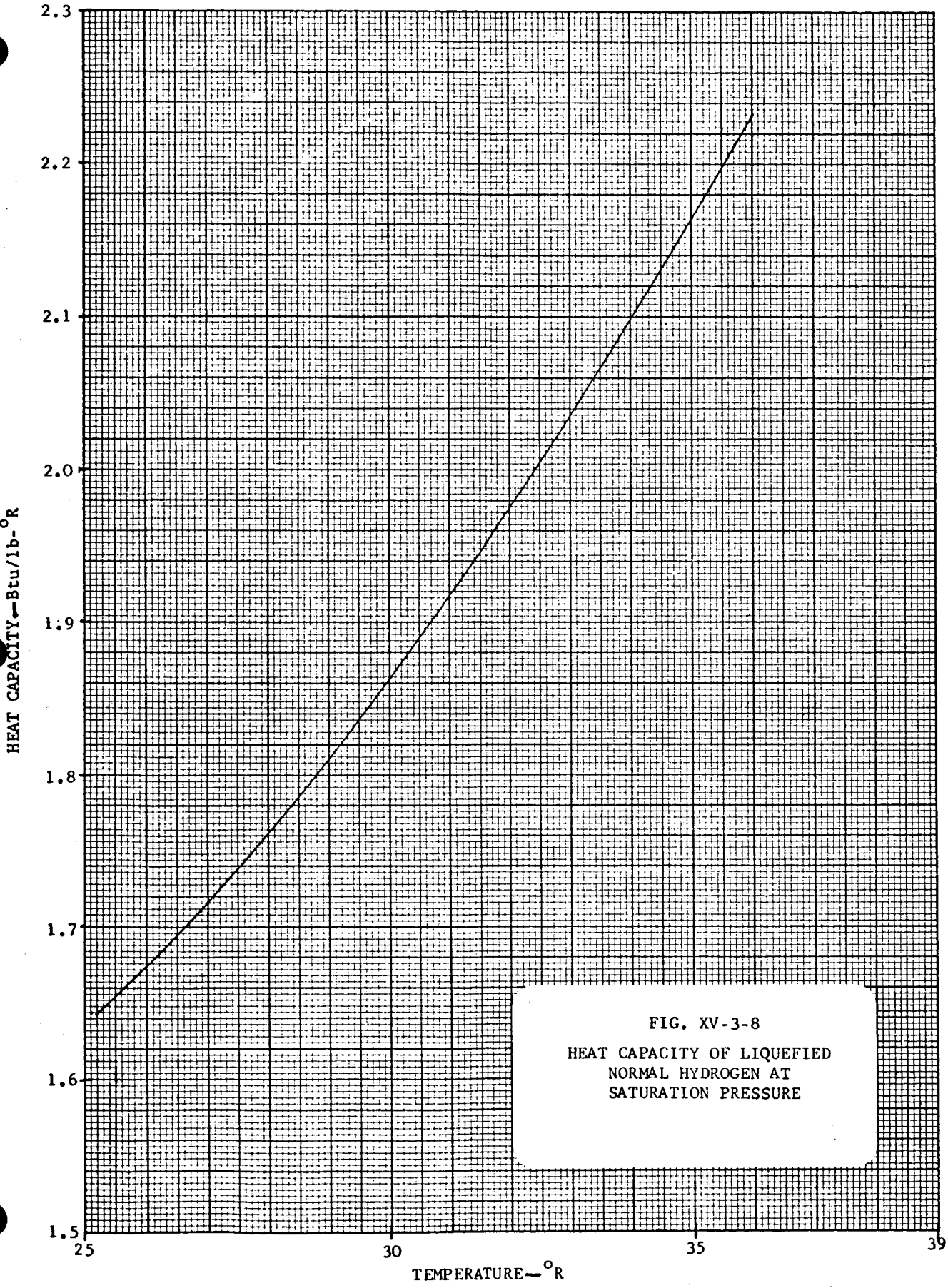


FIG. XV-3-8

HEAT CAPACITY OF LIQUEFIED NORMAL HYDROGEN AT SATURATION PRESSURE

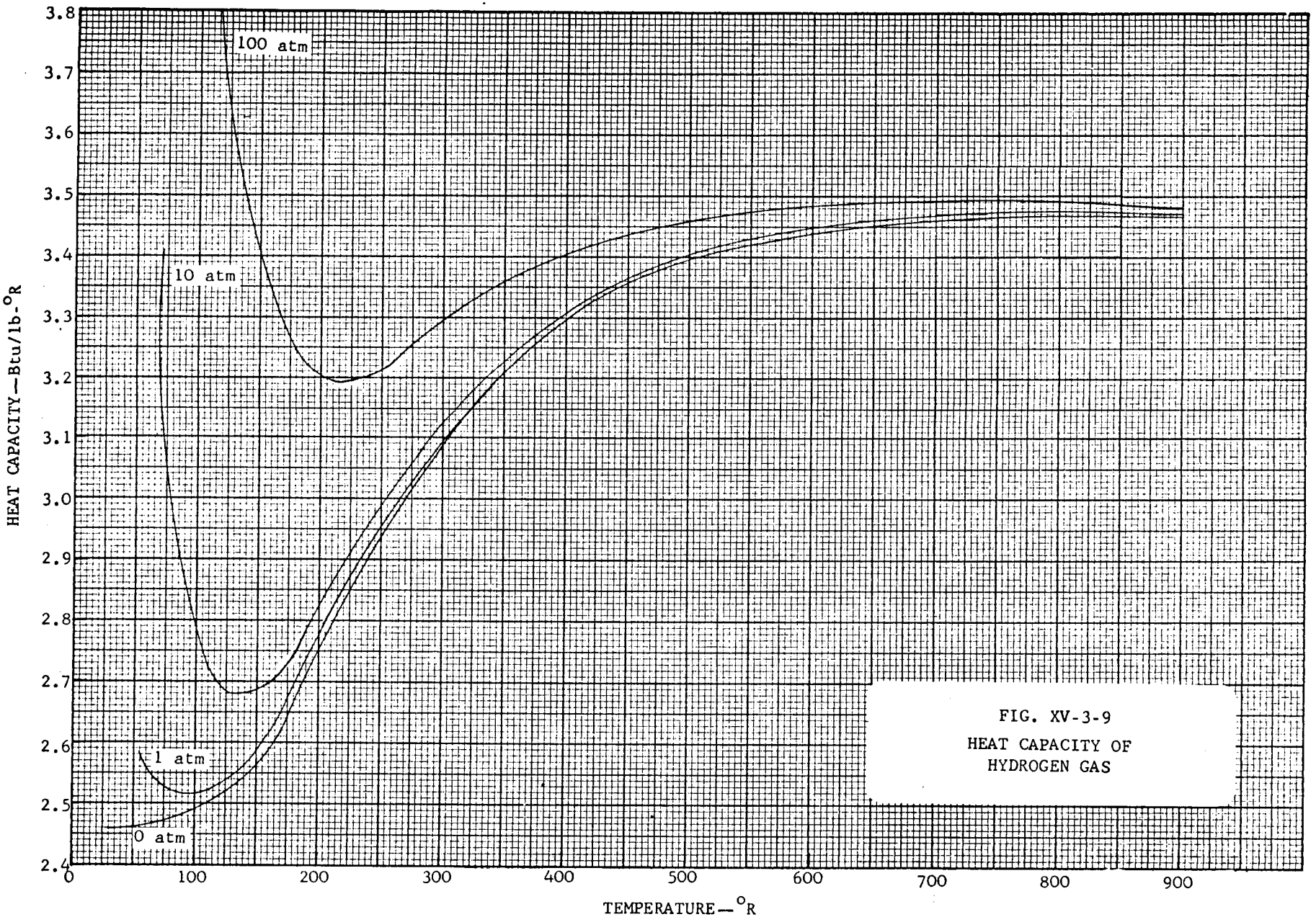


FIG. XV-3-9
HEAT CAPACITY OF
HYDROGEN GAS

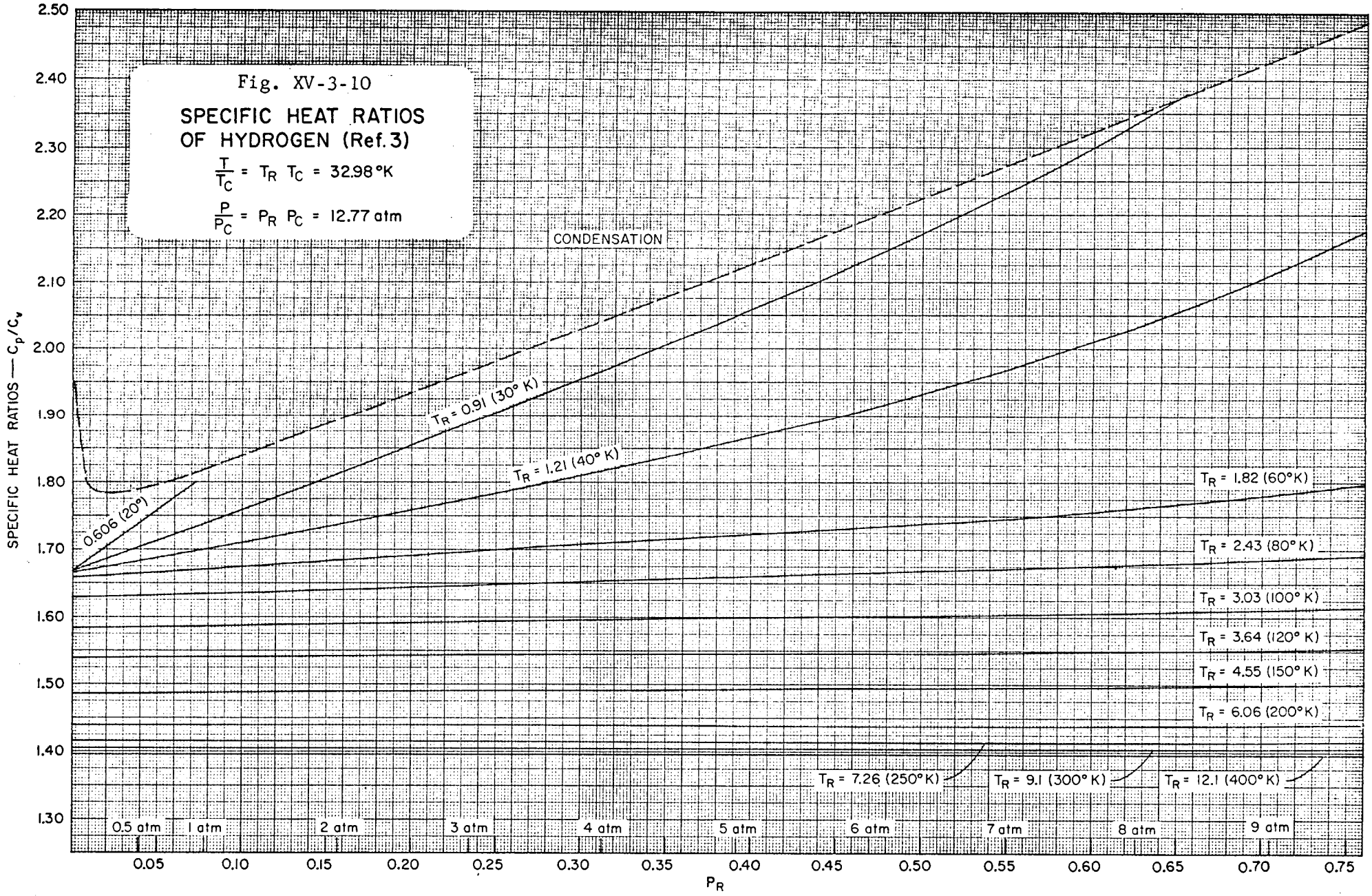


Fig. XV-3-10
SPECIFIC HEAT RATIOS OF HYDROGEN (Ref. 3)
T/T_C = T_R T_C = 32.98°K
P/P_C = P_R P_C = 12.77 atm
CONDENSATION
T_R = 0.91 (30° K)
T_R = 1.21 (40° K)
0.606 (20°)
T_R = 1.82 (60°K)
T_R = 2.43 (80° K)
T_R = 3.03 (100° K)
T_R = 3.64 (120° K)
T_R = 4.55 (150° K)
T_R = 6.06 (200°K)
T_R = 7.26 (250°K)
T_R = 9.1 (300° K)
T_R = 12.1 (400° K)
0.5 atm
1 atm
2 atm
3 atm
4 atm
5 atm
6 atm
7 atm
8 atm
9 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
2.50
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75

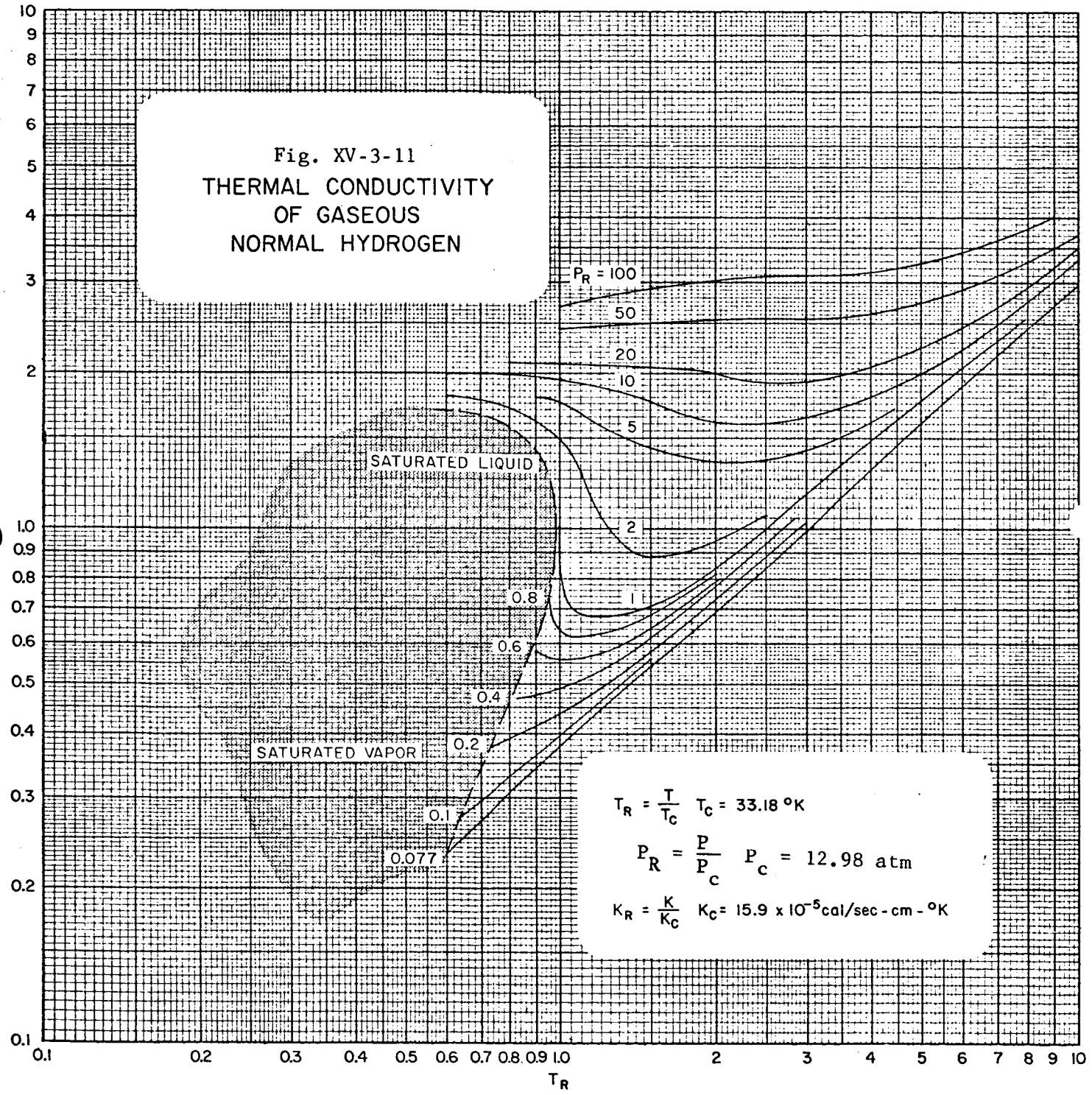


Fig. XV-3-11
THERMAL CONDUCTIVITY
OF GASEOUS
NORMAL HYDROGEN
P_R = 100
50
20
10
5
2
1
0.8
0.6
0.4
0.2
0.1
0.077
SATURATED LIQUID
SATURATED VAPOR
$T_R = \frac{T}{T_c}$ T_c = 33.18 °K
$P_R = \frac{P}{P_c}$ P_c = 12.98 atm
$K_R = \frac{K}{K_c}$ K_c = 15.9 x 10^{-5} cal/sec - cm - °K
T_R

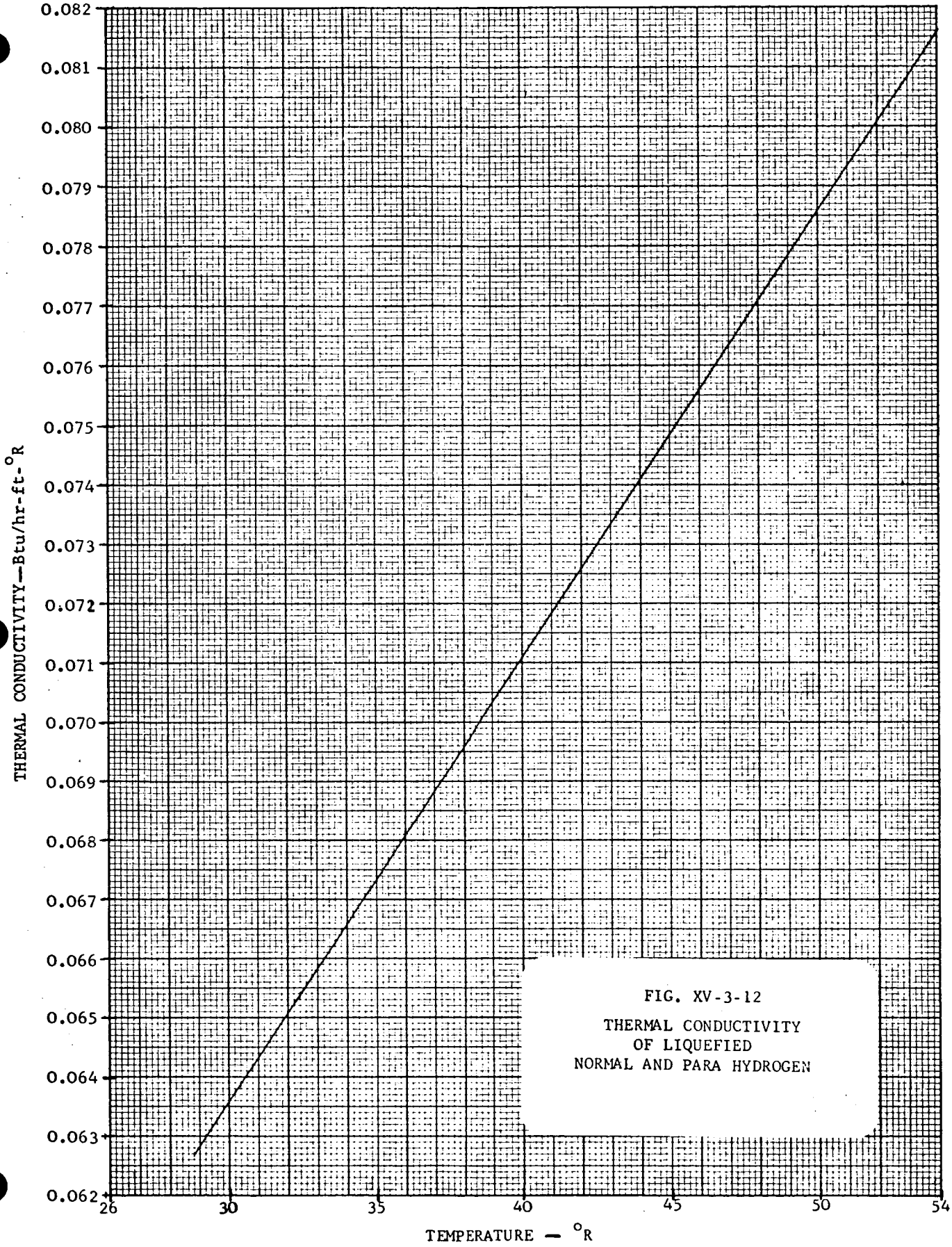


FIG. XV-3-12

THERMAL CONDUCTIVITY
OF LIQUEFIED
NORMAL AND PARA HYDROGEN

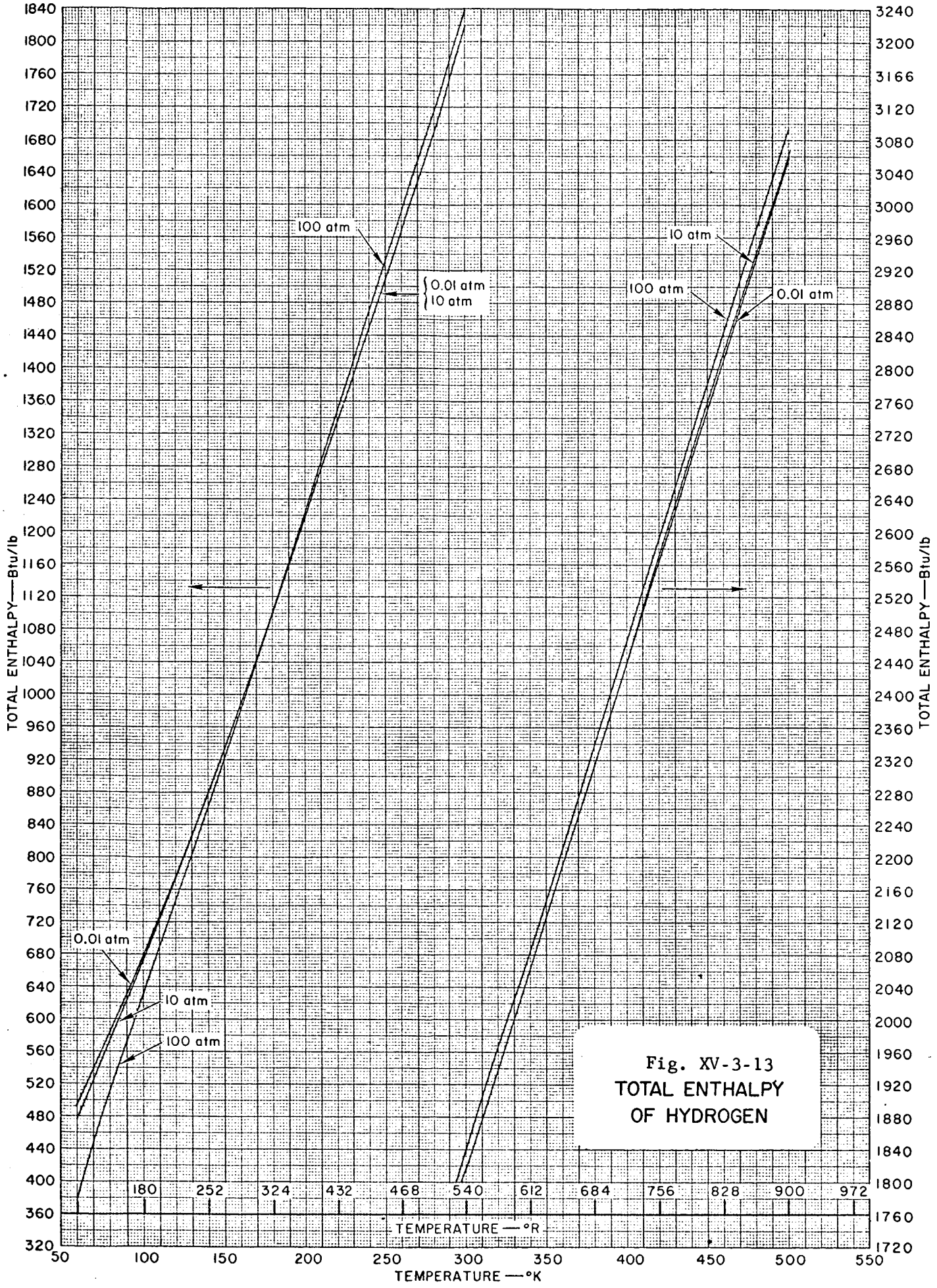


Fig. XV-3-13
TOTAL ENTHALPY
OF HYDROGEN

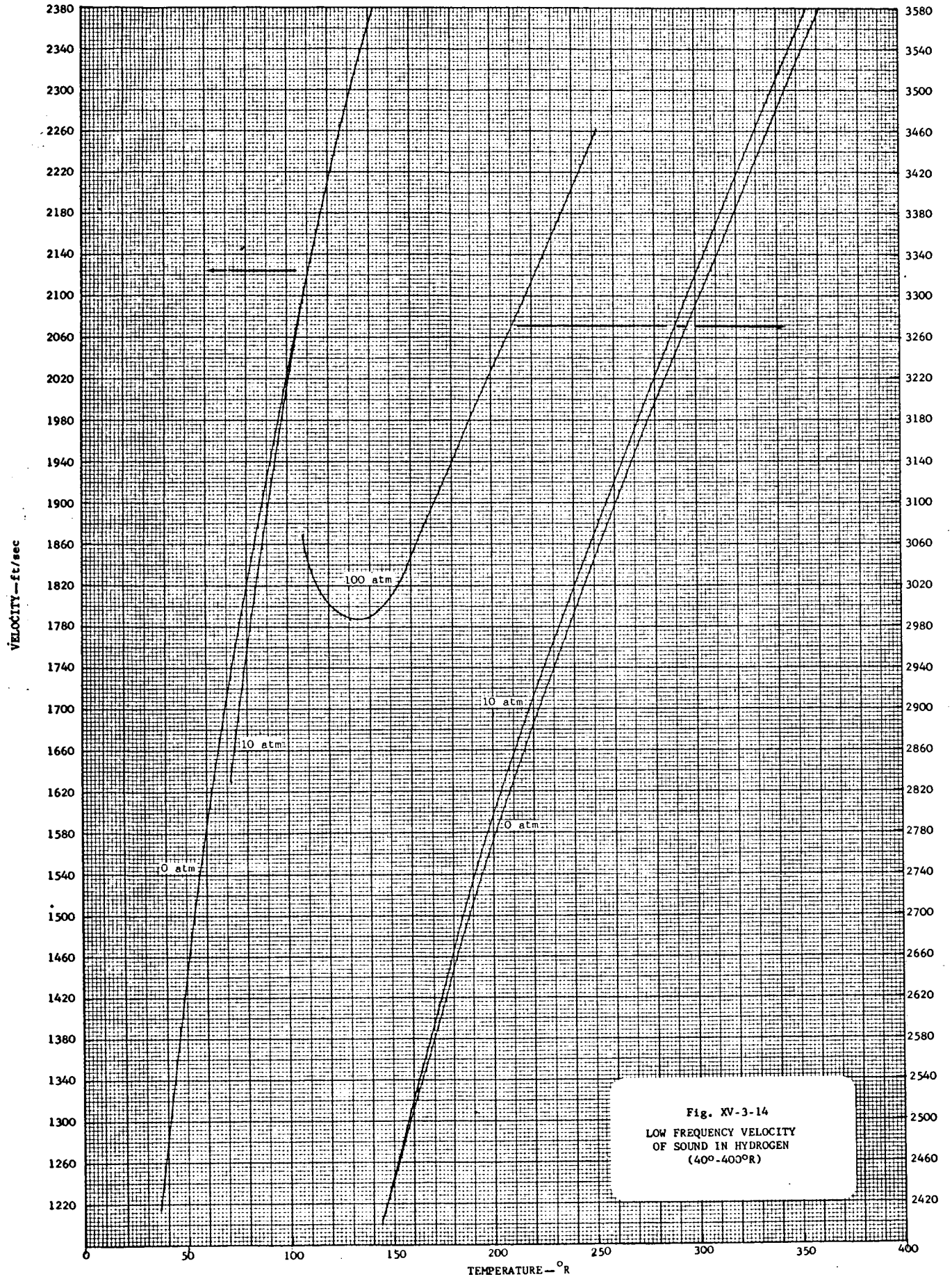


Fig. XV-3-14

LOW FREQUENCY VELOCITY OF SOUND IN HYDROGEN (40°-400°R)

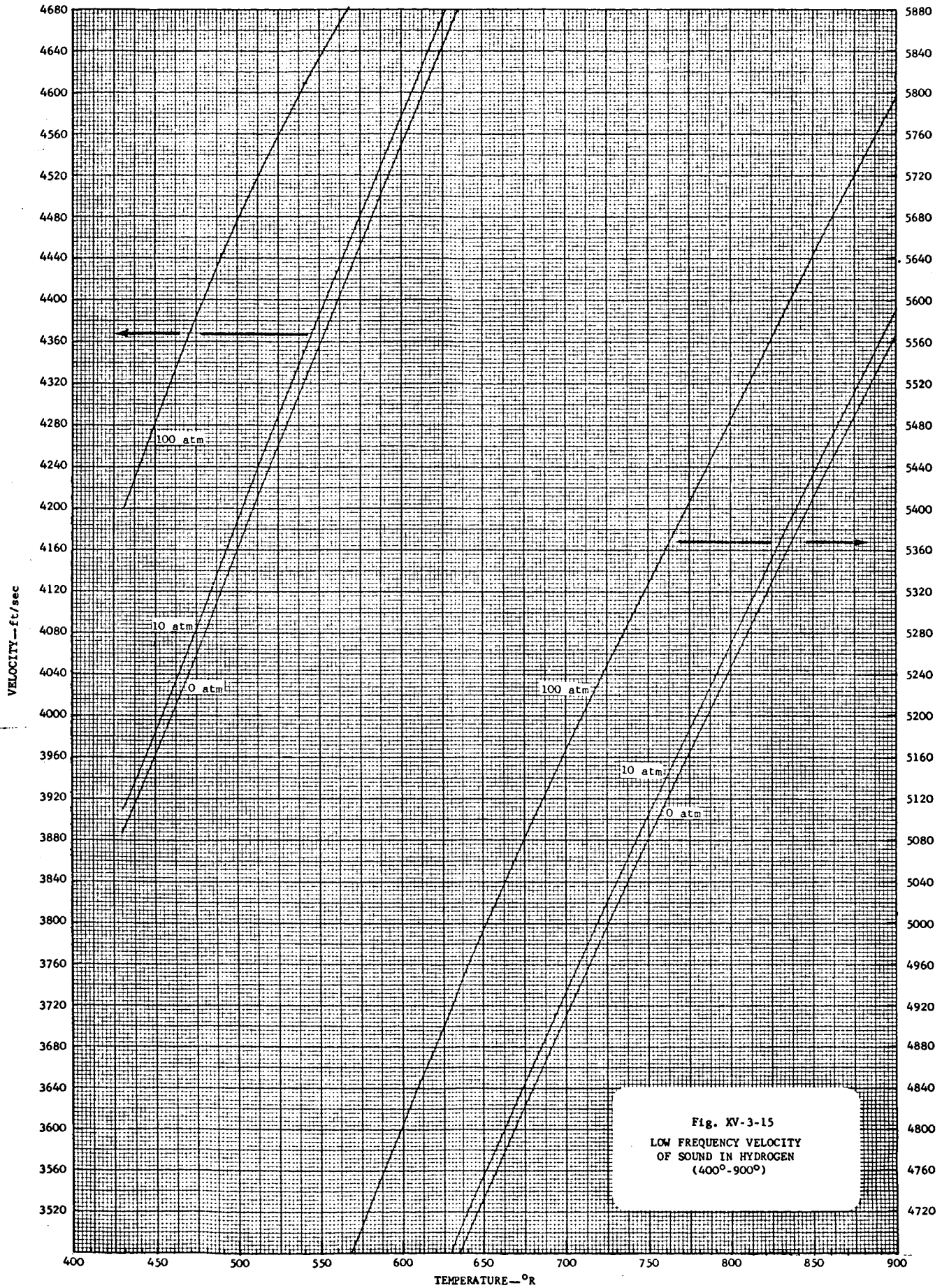


Fig. XV-3-15
LOW FREQUENCY VELOCITY
OF SOUND IN HYDROGEN
(400°-900°)

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Table XV-4-1

PHYSICAL CONSTANTS

OF

HELIUM

		REF.
Molecular Weight	4.003	6
Boiling Point @ 1 atm	-452.06°F	6
Freezing Point @ 1 atm	-457.8°F	6
Specific Volume @ 70°F, 1 atm	96.71 cu-ft/lb	6
Vapor Pressure @ -452°F	14.5 psia	3
Specific Gravity, (Air = 1)	0.137	6
Density		
Liquid		
Gas @ 70°F, 1 atm	0.01034 lb/cu-ft	7
Critical Temperature	-450.2°F	6
Critical Pressure	33.22 psia	6
Critical Density	4.326 lb/cu-ft	6
Latent Heat of Vaporization @ b.p.	10.26 Btu/lb	7
Latent Heat of Fusion @ m.p.	1.49 Btu/lb	9
Specific Heat of Gas		
c_p @ 70°F	1.248 Btu/lb-°F	6
c_v @ 60°F	0.752 Btu/lb-°F	6
Specific Heat Ratio, c_p/c_v @ 60°F	1.660	6
Thermal Conductivity @ 32°F	0.08235 Btu/hr-ft-°F	6
Viscosity		
Liquid		
Gas @ 60°F, 1 atm	1.32×10^{-5} lb/ft-sec	6
Solubility in Water @ 68°F	1.41×10^{-4} cu-ft/lb	6
Surface Tension @ -454°F	1.64×10^{-5} lb/ft	8

Table XV-4-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR HELIUM
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	20.4998	21.1810	15579.9	301.267
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	3.28373	3.39283	249.563	4.82577
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	11.3888	11.7672	8655.48	167.370
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.182429	0.188490	138.646	2.68097
lb/mole/ft^3	0.730228	0.754189	554.973	10.7314

Table XV-4-2

MELTING POINT OF HELIUM (Ref. 4)

TEMPERATURE		PRESSURE	TEMPERATURE		PRESSURE
°K	°R	atm	°K	°R	atm
50.0	90.0	7273.0	4.23	7.61	140.5
45.0	81.0	6171.0	3.59	6.46	108.8
40.0	72.0	5137.0	3.065	5.517	81.5
35.0	63.0	4171.0	2.63	4.73	62.8
30.0	54.0	3375.0	2.295	4.131	48.6
25.0	45.0	2465.0	1.94	3.49	35.7
20.0	36.0	1738.0	1.76	3.17	29.8
15.0	27.0	1105.0	1.605	2.889	27.4
10.0	18.0	581.0	1.42	2.56	26.5
5.0	9.0	196.6	1.22	2.20	25.3
4.5	8.1	156.0			

(See Figure XV-4-1)

Table XV-4-3

VAPOR PRESSURE OF LIQUEFIED HELIUM (Ref. 3)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
1.0	1.8	0.00231	3.0	5.40	3.53
1.2	2.16	0.0119	3.2	5.76	4.68
1.4	2.52	0.0404	3.4	6.12	6.09
1.6	2.88	0.101	3.6	6.48	7.74
1.8	3.24	0.241	3.8	6.74	9.68
2.0	3.6	0.458	4.0	7.20	11.9
2.2	3.96	0.79	4.2	7.56	14.5
2.4	4.32	1.23	4.4	7.82	17.3
2.6	4.68	1.81	4.6	8.28	20.8
2.8	5.04	2.58	4.8	8.64	24.5
			5.0	9.00	28.7
			5.2	9.36	33.1

(See Figure XV-4-2)

Table XV-4-4

VAPOR PRESSURE OF SOLID HELIUM (Ref. 4)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
1.15	2.07	371.37	18.4	33.12	22467.60
1.20	2.16	372.10	18.9	34.02	23434.56
1.30	2.34	374.75	20.2	36.36	25965.72
1.40	2.52	379.30	20.4	36.72	26932.68
1.50	2.70	386.80	21.1	37.98	28056.06
1.60	2.88	398.70	21.4	38.52	29151.00
1.70	3.06	417.22	22.7	40.86	30857.40
1.75	3.15	430.59	23.1	41.58	32137.20
12.2	21.96	11759.94	24.1	43.38	35407.80
13.0	23.40	13068.18	25.6	46.08	37540.80
14.7	26.46	15727.32	25.8	46.44	39531.60
15.5	27.90	17177.76	27.9	50.22	42091.20
16.7	30.06	19111.68	29.6	53.28	46499.40
18.1	32.58	21728.16	31.2	56.16	50196.60

(See Figure XV-4-3)

Table XV-4-5

SURFACE TENSION OF SATURATED LIQUID HELIUM AGAINST ITS OWN VAPOR (Ref. 3)

TEMPERATURE		SURFACE TENSION
°K	°R	dynes/cm
1.00	1.80	0.346
1.50	2.70	0.333
2.00	3.60	0.307
2.18	3.92	0.295
2.50	4.50	0.264
3.00	5.40	0.214
3.50	6.30	0.164
4.00	7.20	0.112
4.50	8.10	0.062
5.00	9.00	0.011
5.12	9.22	0.000

(See Figure XV-4-4)

Table XV-4-6

DENSITY OF SATURATED HELIUM LIQUID AND VAPOR (Ref. 2)

TEMPERATURE		DENSITY—lb/ft^3	
°K	°R	Liquid	Vapor
2.2	3.96	9.143	0.07735
2.4	4.32	9.084	0.1134
2.6	4.68	9.009	0.1584
2.8	5.04	8.918	0.2131
3.0	5.40	8.811	0.2786
3.2	5.76	8.689	0.357
3.4	6.12	8.549	0.450
3.6	6.48	8.392	0.560
3.8	6.84	8.218	0.6899
4.0	7.20	8.026	0.8453
4.2	7.56	7.815	1.030
4.4	7.92	7.585	1.254
4.6	8.28	7.304	1.533
4.8	8.64	6.911	1.899
5.0	9.00	6.280	2.432
5.1	9.18	5.790	2.878
5.15	9.270	5.41	3.22
5.18	9.324	4.91	3.61
5.194	9.349	4.245	4.25

Table XV-4-7

DENSITY OF HELIUM (Ref. 10, 11, 12, 13)

TEMP. °R \ PRESSURE psia	DENSITY lb/ft^3									
	14.7	50	150	400	600	900	1500	2500	4000	6000
20 °	0.2915	1.130	4.785	-	-	-	-	-	-	-
35	0.1584	0.5414	1.616	3.909	5.291	6.849	9.091	11.111	14.290	16.667
60	0.09158	0.3101	0.9141	2.302	3.274	4.525	6.494	9.091	11.111	14.286
110	0.04985	0.1688	0.4998	1.287	1.877	2.700	4.149	6.135	8.403	11.111
160	0.03425	0.1161	0.3447	0.8961	1.318	1.919	3.021	4.619	6.623	8.772
210	0.02609	0.08850	0.2634	0.6882	1.016	1.489	2.373	3.694	5.405	7.299
260	0.02107	0.07153	0.2131	0.5587	0.8271	1.241	1.954	3.076	4.566	6.250
310	0.01767	0.05999	0.1789	0.4701	0.6974	1.029	1.661	2.635	3.953	5.465
360	0.01522	0.05168	0.1542	0.4060	0.6031	0.8913	1.445	2.305	3.472	4.878
460	0.01191	0.04045	0.1209	0.3190	0.4746	0.7037	1.147	1.844	2.809	3.980
560	0.009785	0.03323	0.09940	0.2627	0.3914	0.5814	0.9506	1.538	2.358	3.367
660	0.008299	0.02821	0.08439	0.2233	0.3331	0.4953	0.8123	1.318	2.033	2.916
760	0.007210	0.02450	0.07331	0.1942	0.2899	0.4316	0.7087	1.154	1.789	2.577
860	0.006369	0.02165	0.06481	0.1718	0.2566	0.3823	0.6289	1.027	1.595	2.310

(See Figure XV-4-5)

Table XV-4-8

VISCOSITY OF LIQUID HELIUM (Ref. 5)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	micropoises	°K	°R	micropoises
1.20	2.16	1.35	2.24	4.03	17.60
1.60	2.88	2.80	2.40	4.32	20.20
1.80	3.24	4.70	2.80	5.04	23.80
2.00	3.60	8.40	3.00	5.40	25.10
2.10	3.70	12.10	3.30	5.94	26.70
2.15	3.87	16.00	3.60	6.48	27.80
2.16	3.89	23.55 lambda point	4.00	7.20	28.90

(See Figure XV-4-6)

Table XV-4-9

VISCOSITY OF HELIUM GAS AT ONE ATMOSPHERE (Ref. 1)

TEMPERATURE		VISCOSITY	TEMPERATURE		VISCOSITY
°K	°R	lb/ft-hr	°K	°R	lb/ft-hr
4.0	7.2	0.00298	280.0	504.0	0.04659
10.0	18.0	0.00539	300.0	540.0	0.04872
20.0	36.0	0.00845	320.0	576.0	0.05079
40.0	72.0	0.01322	340.0	612.0	0.05283
60.0	108.0	0.01719	360.0	648.0	0.05482
80.0	144.0	0.02072	380.0	684.0	0.05677
100.0	180.0	0.02393	400.0	720.0	0.05868
120.0	216.0	0.02693			
140.0	252.0	0.02975			
160.0	288.0	0.03243			
180.0	324.0	0.03500			
200.0	360.0	0.03747			
220.0	396.0	0.03986			
240.0	432.0	0.04217			
260.0	468.0				

(See Figure XV-4-7)

Table XV-4-10

HEAT OF VAPORIZATION OF HELIUM (Ref. 2)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
^{o}K	^{o}R	Btu/lb	^{o}K	^{o}R	Btu/lb
2.2	3.96	9.816	4.2	7.56	9.000
2.4	4.32	9.935	4.4	7.92	8.463
2.6	4.68	10.03	4.6	8.28	7.733
2.8	5.04	10.12	4.8	8.64	6.713
3.0	5.40	10.17	5.0	9.00	5.166
3.2	5.76	10.16	5.1	9.18	3.866
3.4	6.12	10.08	5.15	9.27	2.878
3.6	6.48	9.956	5.18	9.32	1.718
3.8	6.84	9.741			
4.0	7.20	9.419			

(See Figure XV-4-8)

Table XV-4-11

HEAT CAPACITY OF LIQUID HELIUM AT SATURATION PRESSURE (Ref. 3)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
^{o}K	^{o}R	Btu/lb-^{o}R	^{o}K	^{o}R	Btu/lb-^{o}R
1.79	3.22	0.672	3.39	6.10	0.710
1.84	3.31	0.779	3.59	6.46	0.779
1.89	3.40	0.906	3.79	6.82	0.860
1.99	3.58	1.24	3.99	7.18	0.953
2.04	3.67	1.47	4.19	7.54	1.07
2.09	3.76	1.80	4.39	7.90	1.22
2.14	3.85	2.23	4.59	8.26	1.42
2.1635	3.8943	3.01	4.79	8.62	1.80
2.19	3.94	0.951	4.99	8.98	2.75
2.29	4.12	0.631	5.04	9.07	3.23
2.39	4.30	0.569			
2.59	4.66	0.542			
2.79	5.02	0.559			
2.99	5.38	0.595			
3.19	5.74	0.643			

(See Figure XV-4-9)

Table XV-4-12

HEAT CAPACITY OF GASEOUS HELIUM (Ref. 1)

TEMPERATURE		HEAT CAPACITY, C_p—Btu/lb-°R					
°K	°R	1 atm	3.40 atm	10.2 atm	40.8 atm	102 atm	408 atm
15.09	27.17	1.313	1.480	1.480			
25.20	47.17	1.220	1.296	1.296	1.364		
47.40	84.67	1.238	1.268	1.268	1.312	1.382	
66.30	119.34	1.242	1.250	1.250	1.274	1.324	
102.59	184.67	1.242	1.242	1.244	1.256	1.280	2.108
130.37	234.67	1.242	1.244	1.244	1.250	1.262	1.330
158.15	284.67	1.240	1.240	1.242	1.246	1.256	1.294
185.93	334.67	1.242	1.242	1.242	1.244	1.248	1.276
227.59	409.67	1.246	1.241	1.242	1.243	1.252	1.259
283.15	509.67	1.235	1.241	1.241	1.242	1.237	1.249
338.71	609.67	1.241	1.241	1.241	1.241	1.241	1.243
394.26	709.67	1.241	1.242	1.241	1.241	1.241	1.245
449.82	809.67	1.244	1.240	1.241	1.238	1.241	1.230
505.37	909.67	1.240	1.240	1.240	1.240	1.240	1.240

Table XV-4-13

THERMAL CONDUCTIVITY OF

LIQUID HELIUM (Ref. 3)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
2.3	4.14	0.0105
2.4	4.32	0.0107
2.6	4.68	0.0113
2.8	5.04	0.0118
3.0	5.4	0.0124
3.5	6.3	0.0137
4.0	7.2	0.0151
4.2	7.56	0.0157

(See Figure XV-4-11)

Table XV-4-14

THERMAL CONDUCTIVITY OF HELIUM GAS AT ONE ATMOSPHERE (Ref. 1)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
2.04	3.67	0.0022
5.37	9.67	0.0063
10.93	19.67	0.0106
16.48	29.67	0.0133
22.04	39.67	0.0160
27.59	49.67	0.0186
33.15	59.67	0.0210
88.71	159.67	0.0400
144.26	259.67	0.0550
199.82	359.67	0.0673
255.37	459.67	0.0792
366.48	659.67	0.1000
477.59	859.67	0.1191

(See Figure XV-4-12)

Table XV-4-15

TOTAL ENTHALPY OF HELIUM (Ref. 10)

ENTHALPY-Btu/lb											
Temp. °R	Pressure psia / °F	14.7	50	150	400	600	900	1500	2500	4000	6000
20	-440	26.75	24.9	21.3							
35	-425	46.2	45.3	43.5	41.5	41.3	43.0				
60	-400	76.9	76.7	75.9	75.7	75.4	75.0	75.2			
110	-350		139.0	139.3	140.3	141.0	142.1	144.3	148.0	154.0	
160	-300	200.9	201.1	201.8	203.4	204.7	206.6	210.5	217.0	227.0	240.0
210	-250		263.2	264.0	266.0	267.5	269.8	274.5	282.2	293.9	309.4
260	-200	325.1	335.4	362.2	328.6	330.0	332.5	337.6	346.1	358.9	375.9
310	-150		387.4	388.3	390.5	392.3	395.0	400.4	409.0	422.7	440.6
360	-100	449.2	449.5	450.4	452.7	454.5	457.3	462.8	472.0	485.9	504.4
460	0	573.3	573.6	574.6	576.9	576.8	581.7	588.0	596.9	611.2	630.3
560	100	697.4	697.7	698.7	701.1	703.0	705.9	711.7	721.3	735.8	755.2
660	200	821.5	821.8	822.8	825.2	827.1	830.9	835.8	845.5	860.1	879.5
760	300	945.6	946.0	946.9	949.3	951.2	954.1	959.9	989.6	989.6	1004.0
860	400	1070.0	1070.0	1071.0	1073.0	1075.0	1078.0	1084.0	1094.0	1094.0	1127.0
960	500	1194.0	1194.0	1195.0	1197.0	1199.0	1202.0	1208.0	1218.0	1218.0	1251.0
1060	600	1318.0	1318.0	1319.0	1322.0	1323.0	1326.0	1332.0	1342.0	1342.0	1375.0

(See Figure XV-4-13)

Table XV-4-16

LOW FREQUENCY VELOCITY OF SOUND IN HELIUM (Ref. 10)

VELOCITY-ft/sec											
Temp. °R	Temp. °F \ PRESSURE psia	14.7	50	150	400	600	900	1500	2500	4000	6000
60	-400	1110	1112	1121	1153	1184	1233	1341	1555	1687	1816
110	-350	1504	1507	1516	1543	1563	1595	1667	1781	1943	2089
160	-300	1815	1519	1827	1849	1866	1893	1950	2039	2164	2317
210	-250	2080	2083	2095	2110	2127	2159	2198	2276	2385	2529
260	-200	2317	2318	2325	2342	2359	2357	2423	2494	2590	2715
310	-150	2529	2531	2538	2555	2569	2589	2629	2694	2764	2898
360	-100	2730	2725	2732	2751	2764	2783	2820	2881	2966	3066
460	0	3082	3083	3088	3104	3117	3134	3167	3226	3301	3394
560	100	3399	3401	3406	3421	3431	3449	3480	3530	3604	3691
660	200	3690	3691	3696	3710	3723	3736	3765	3815	3882	3967
760	300	3960	3961	3966	3978	3988	4003	4032	4078	4140	4222
860	400	4211	4213	4218	4223	4239	4253	4280	4323	4386	4459
960	500	4450	4451	4458	4466	4477	4489	4515	4558	4615	4692
1060	600	4657	4678	4682	4692	4701	4714	4739	4779	4839	4910

(See Figure XV-4-14)

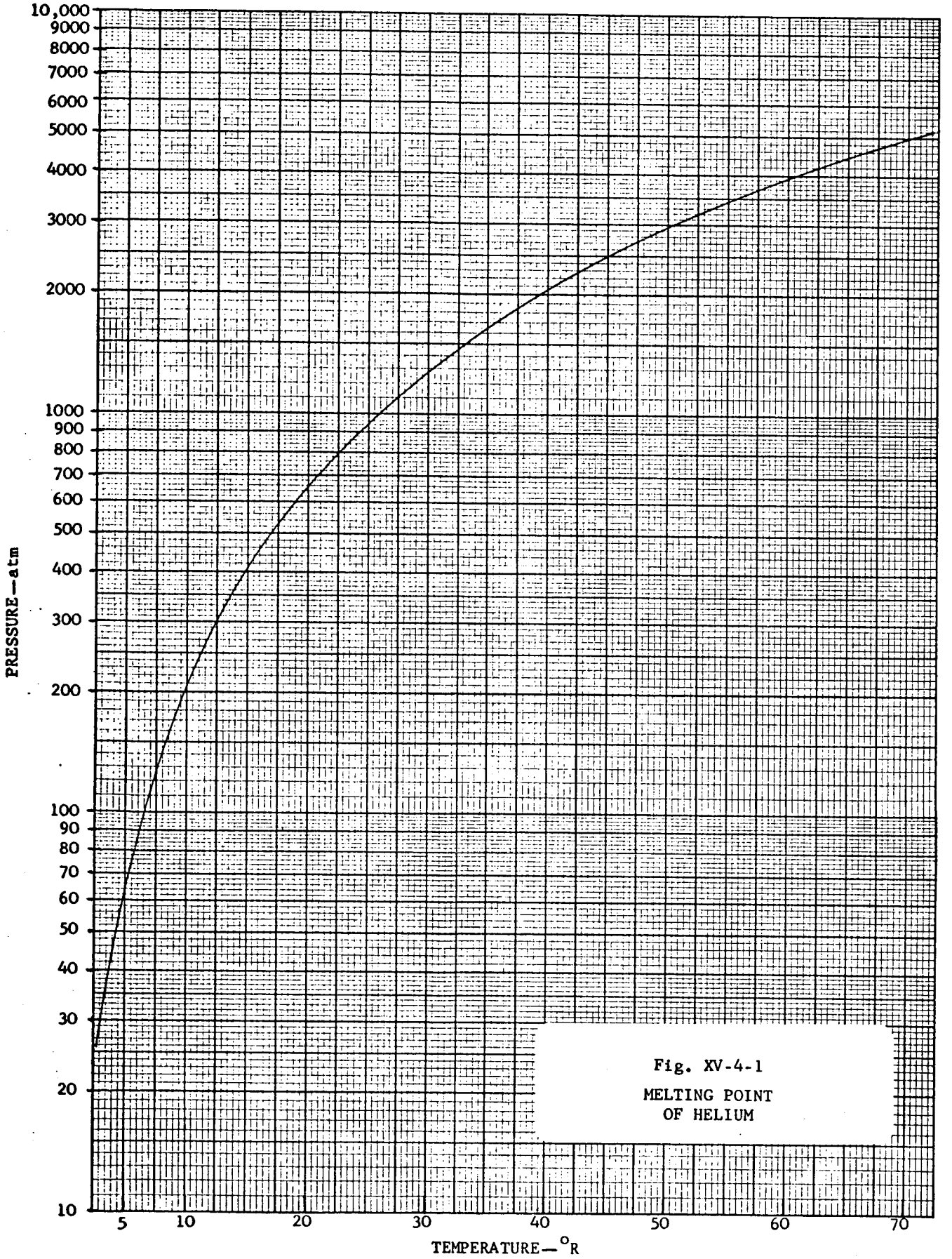


Fig. XV-4-1

MELTING POINT
OF HELIUM

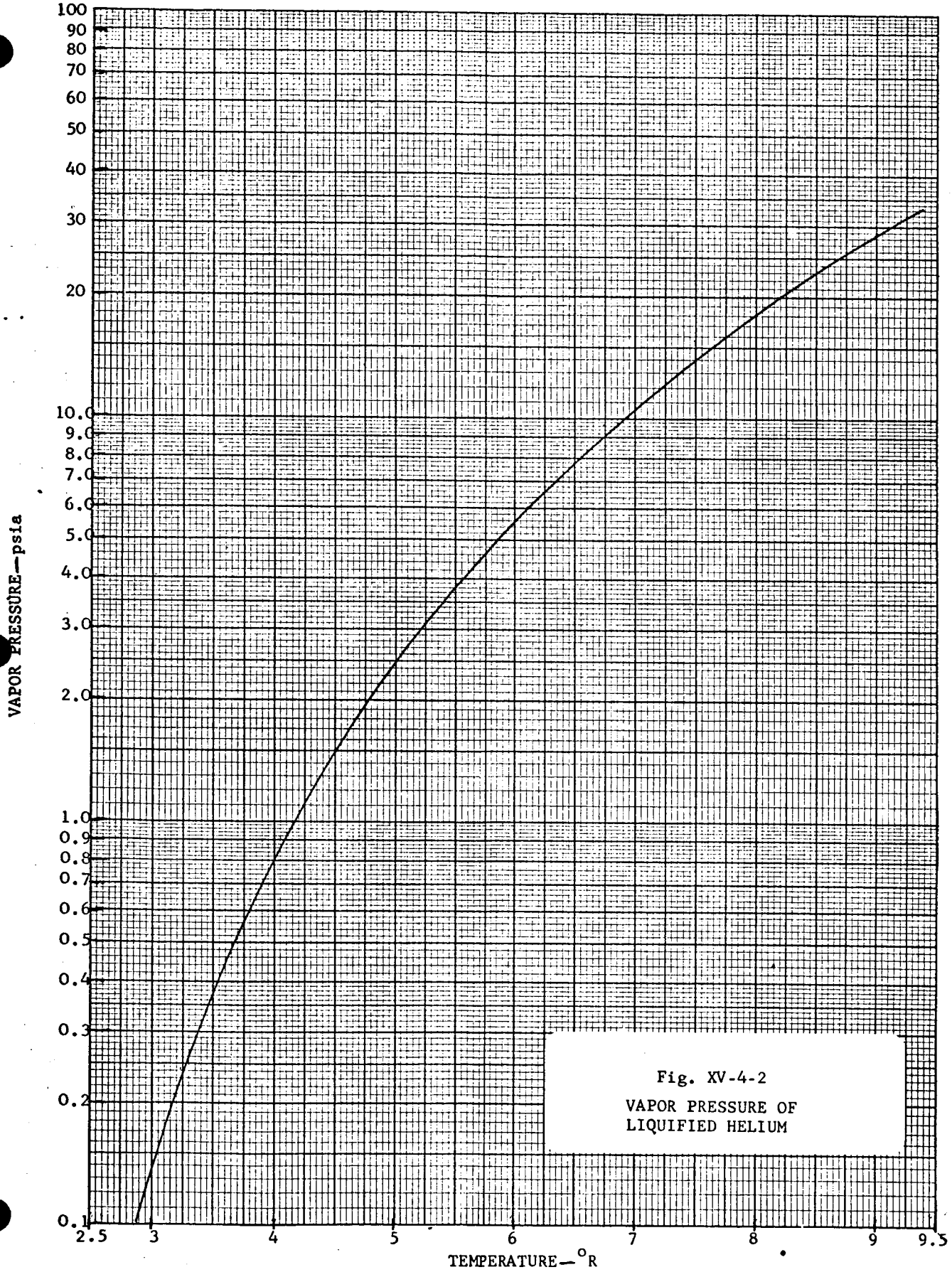


Fig. XV-4-2

VAPOR PRESSURE OF LIQUIFIED HELIUM

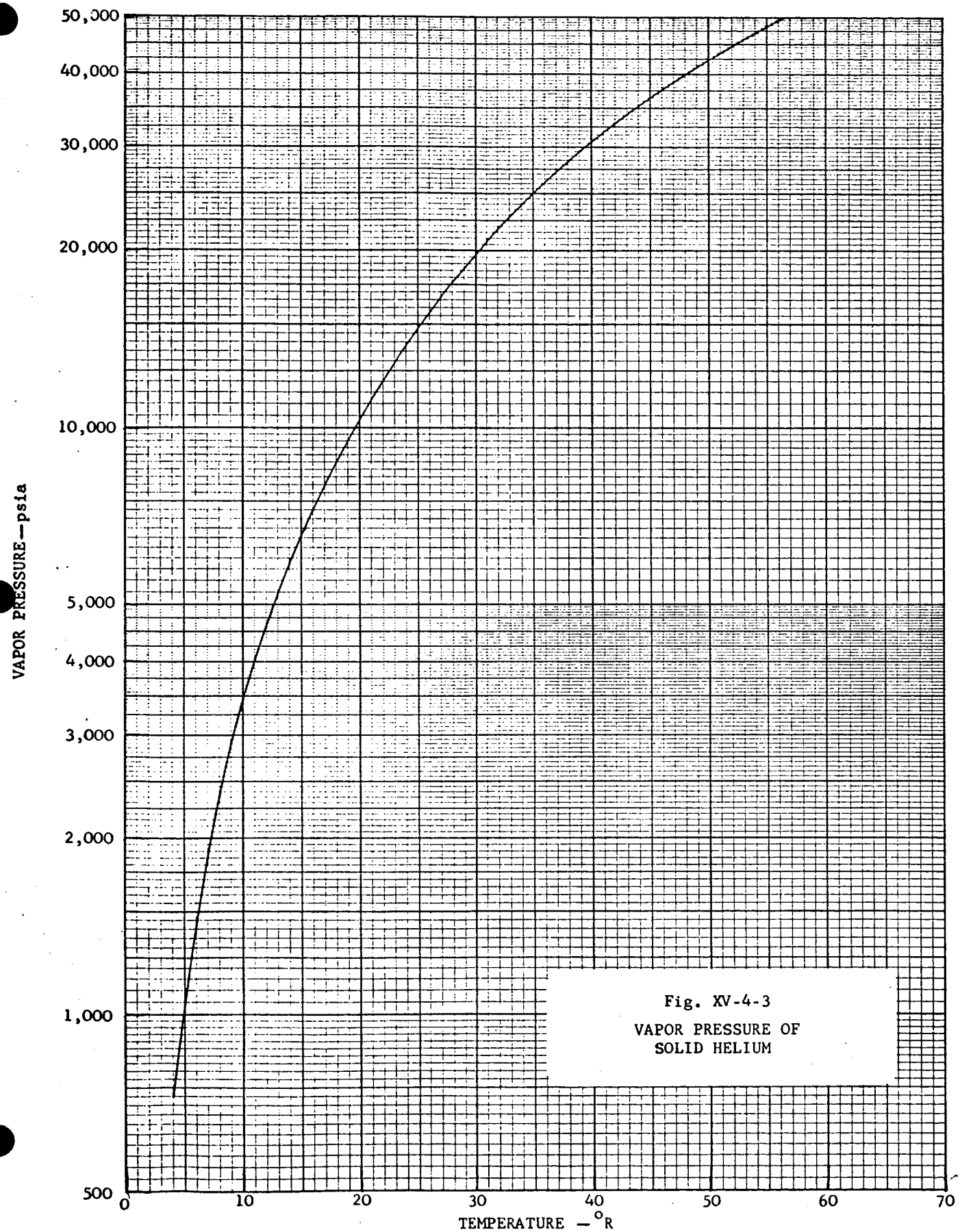


Fig. XV-4-3

VAPOR PRESSURE OF SOLID HELIUM

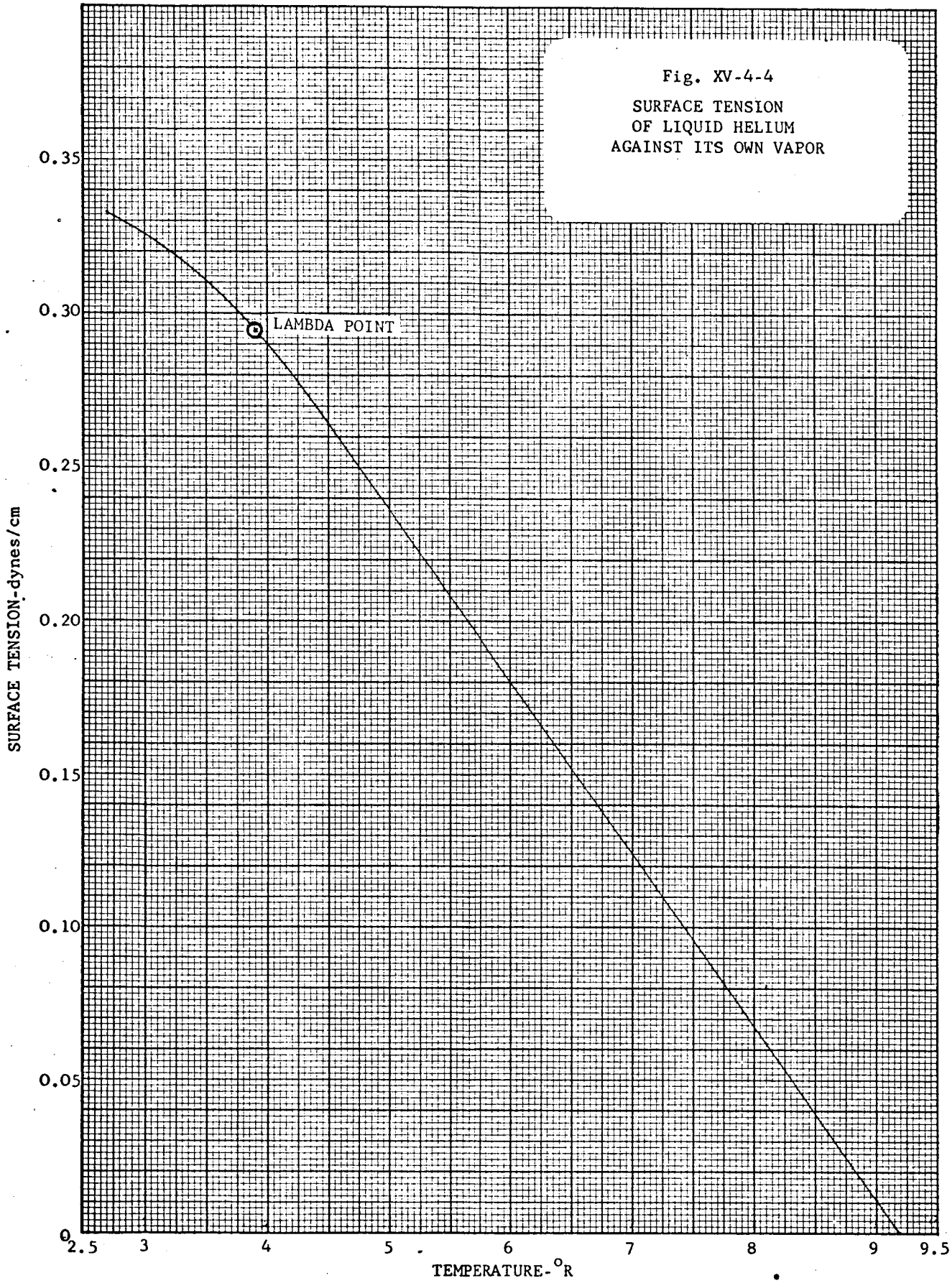
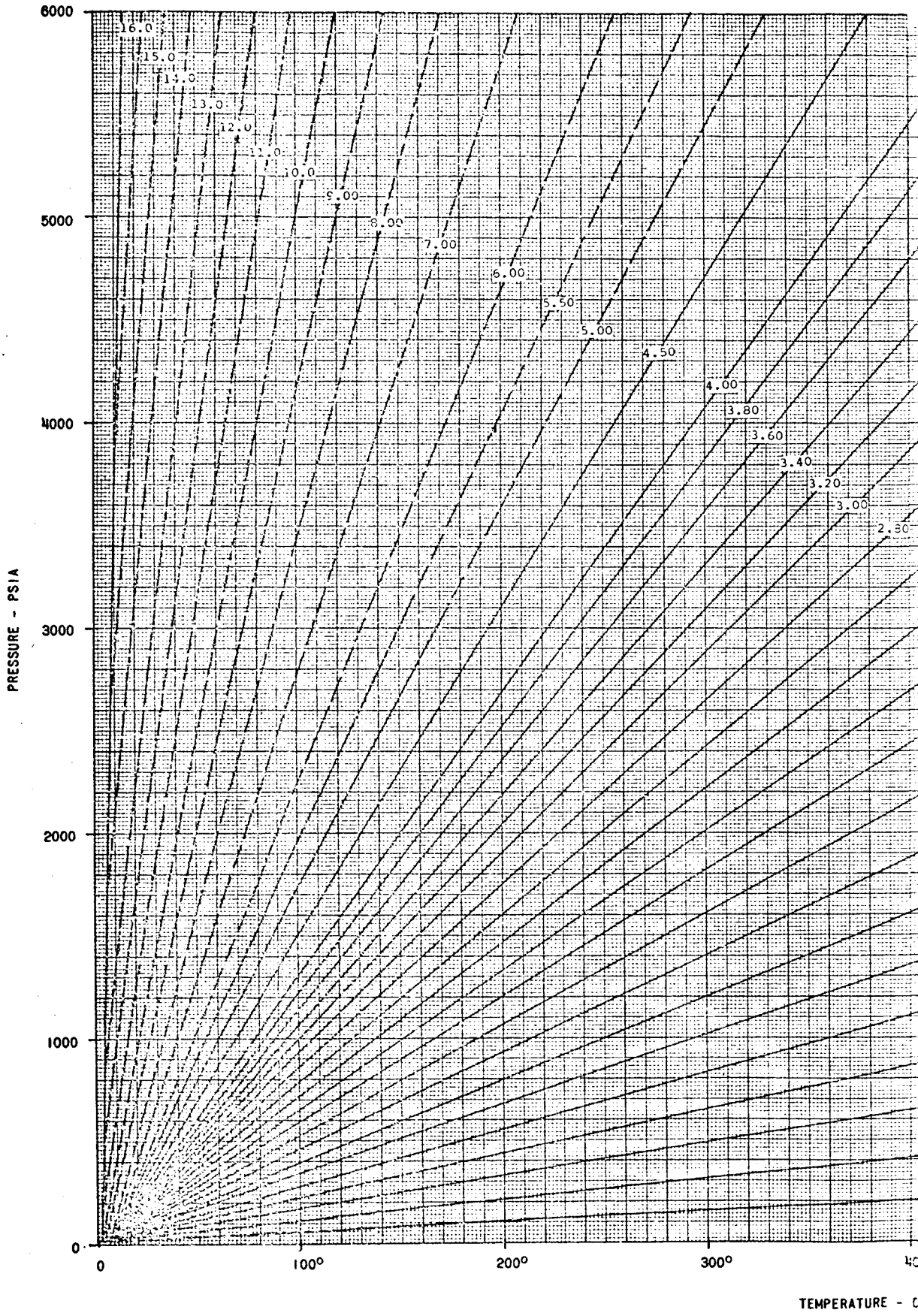


Fig. XV-4-4

SURFACE TENSION
OF LIQUID HELIUM
AGAINST ITS OWN VAPOR


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
0
100°
200°
300°
TEMPERATURE -
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.00
8.00
7.00
6.00
5.50
5.00
4.50
4.00
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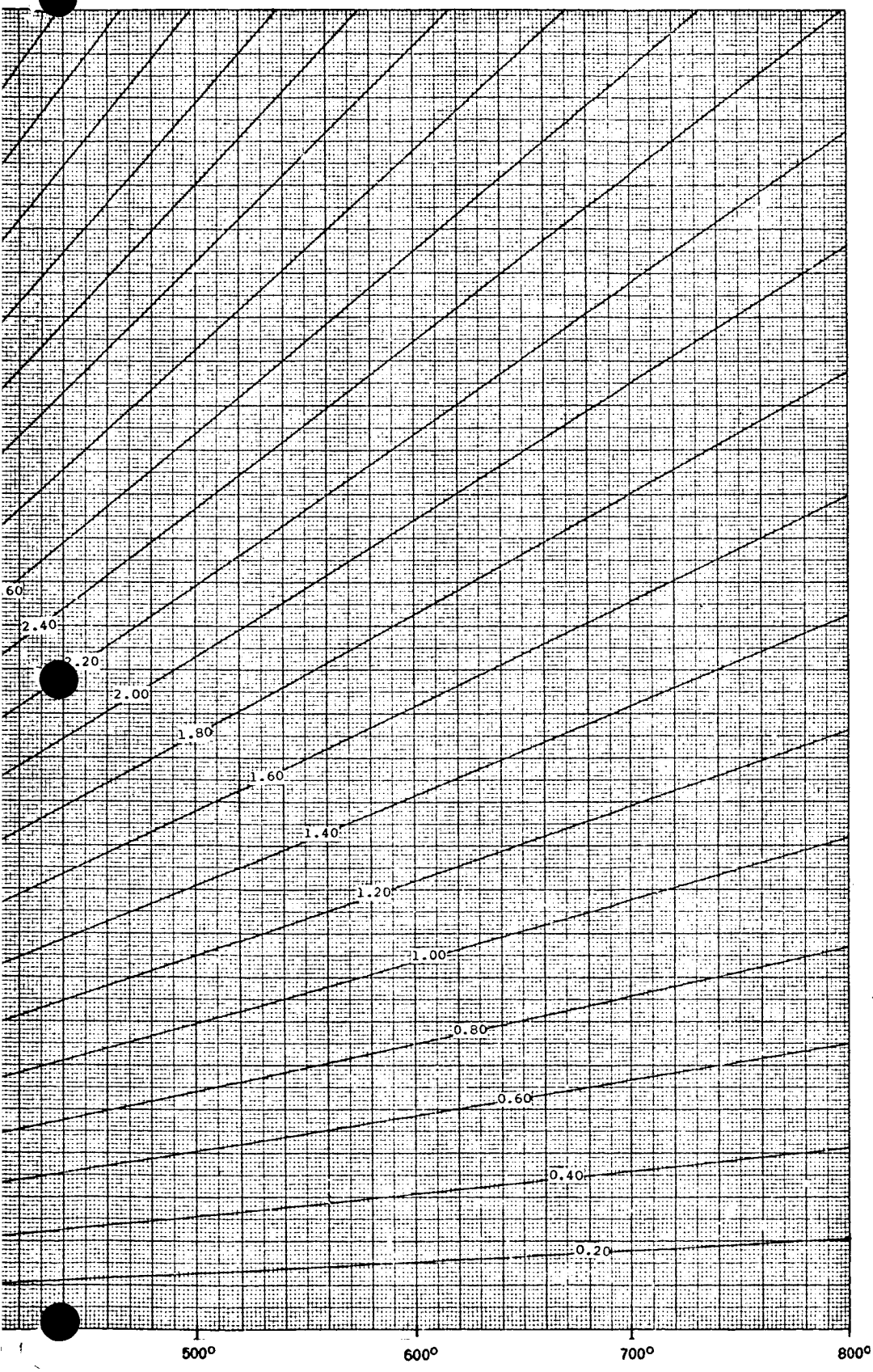
3.60
3.40
3.20
3.00
2.80

XV-4-5-1



REES RANKIN

FIG. XV-4-5
HELIUM (He)

CONSTANT DENSITY (lb/cu.ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

——— COMMONLY ACCEPTED DATA

– – – EXTRAPOLATED OR UNCONFIRMED DATA

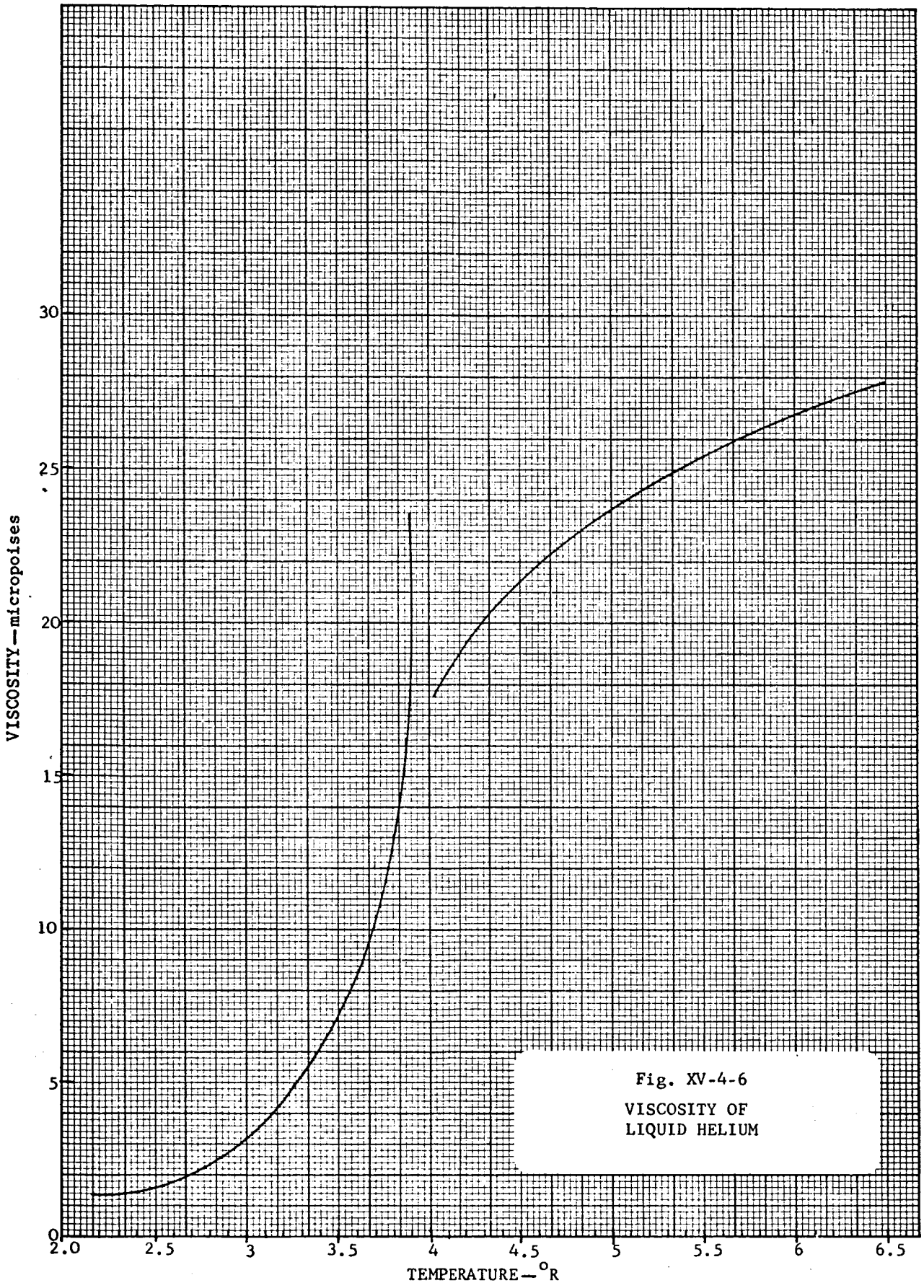


Fig. XV-4-6

VISCOSITY OF
LIQUID HELIUM

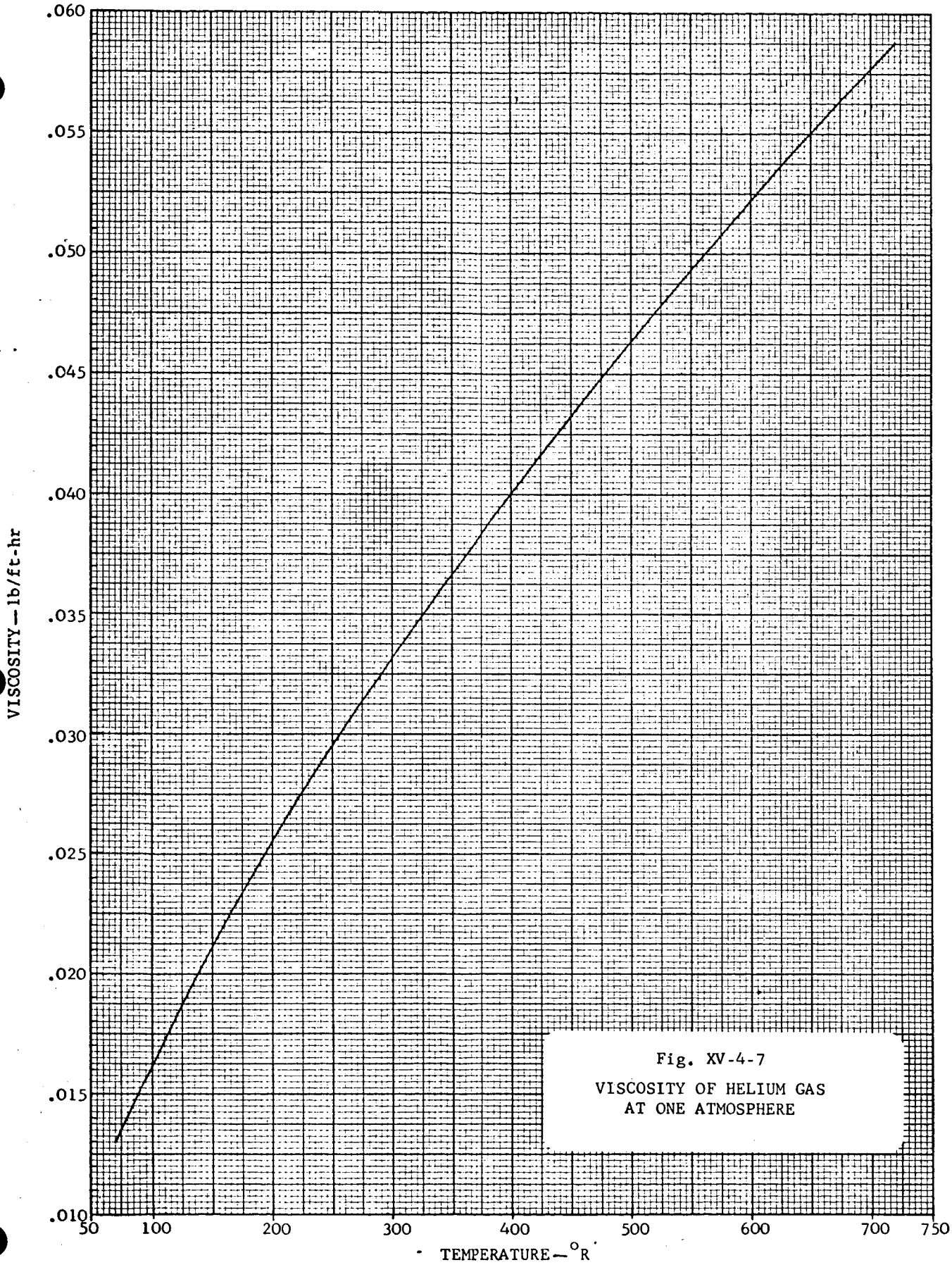


Fig. XV-4-7

VISCOSITY OF HELIUM GAS
AT ONE ATMOSPHERE

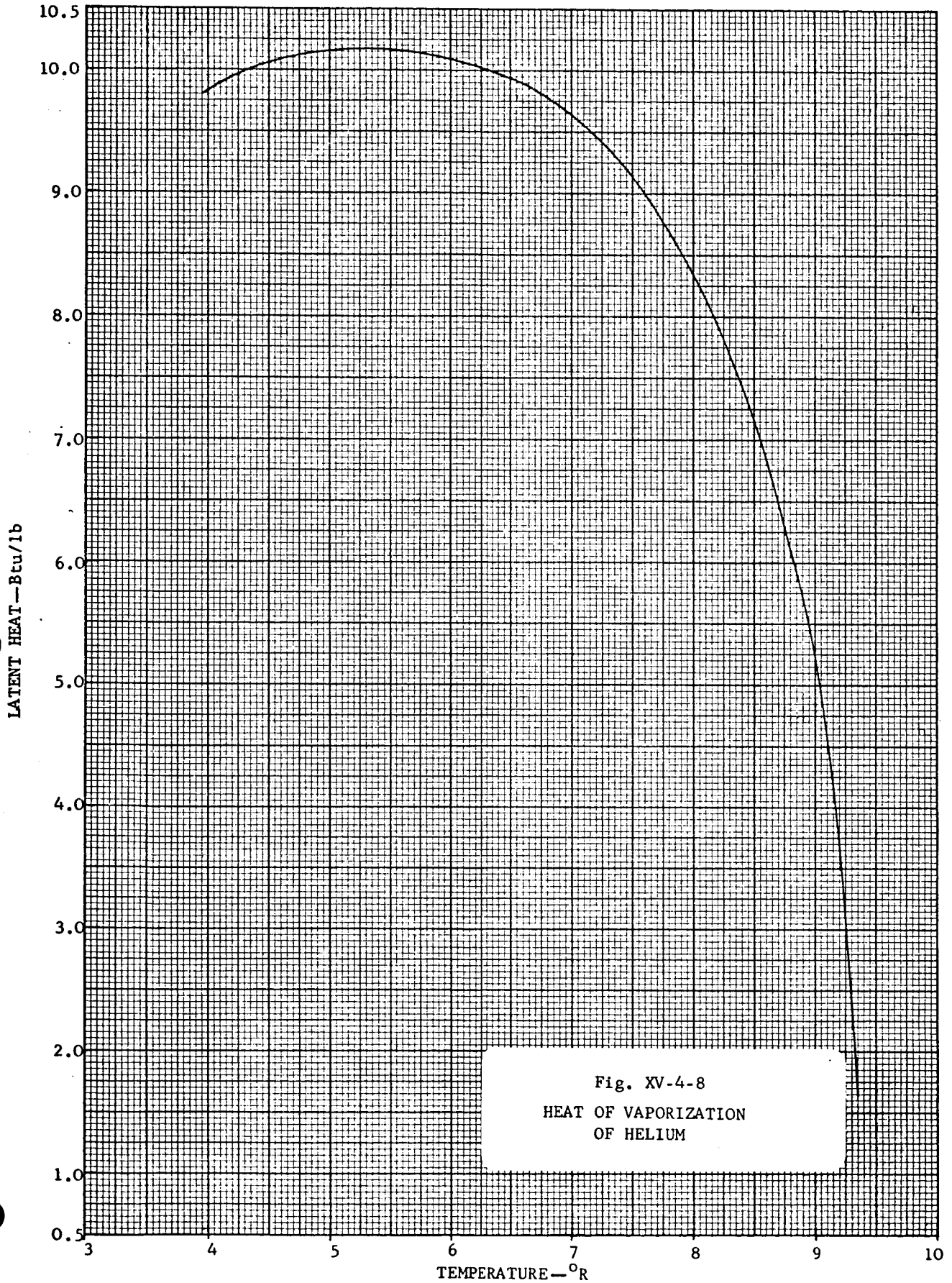


Fig. XV-4-8

HEAT OF VAPORIZATION OF HELIUM

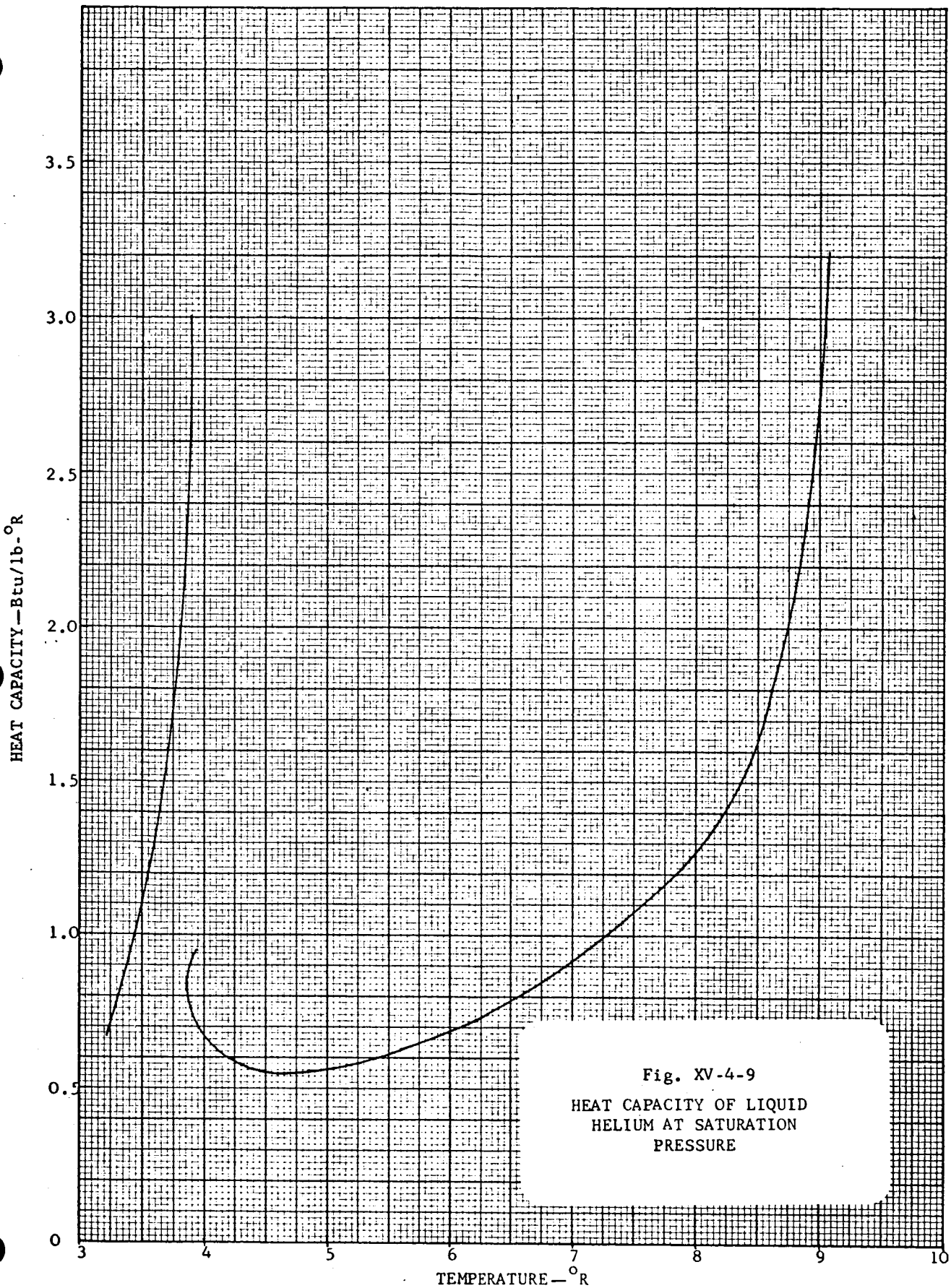


Fig. XV-4-9

HEAT CAPACITY OF LIQUID HELIUM AT SATURATION PRESSURE

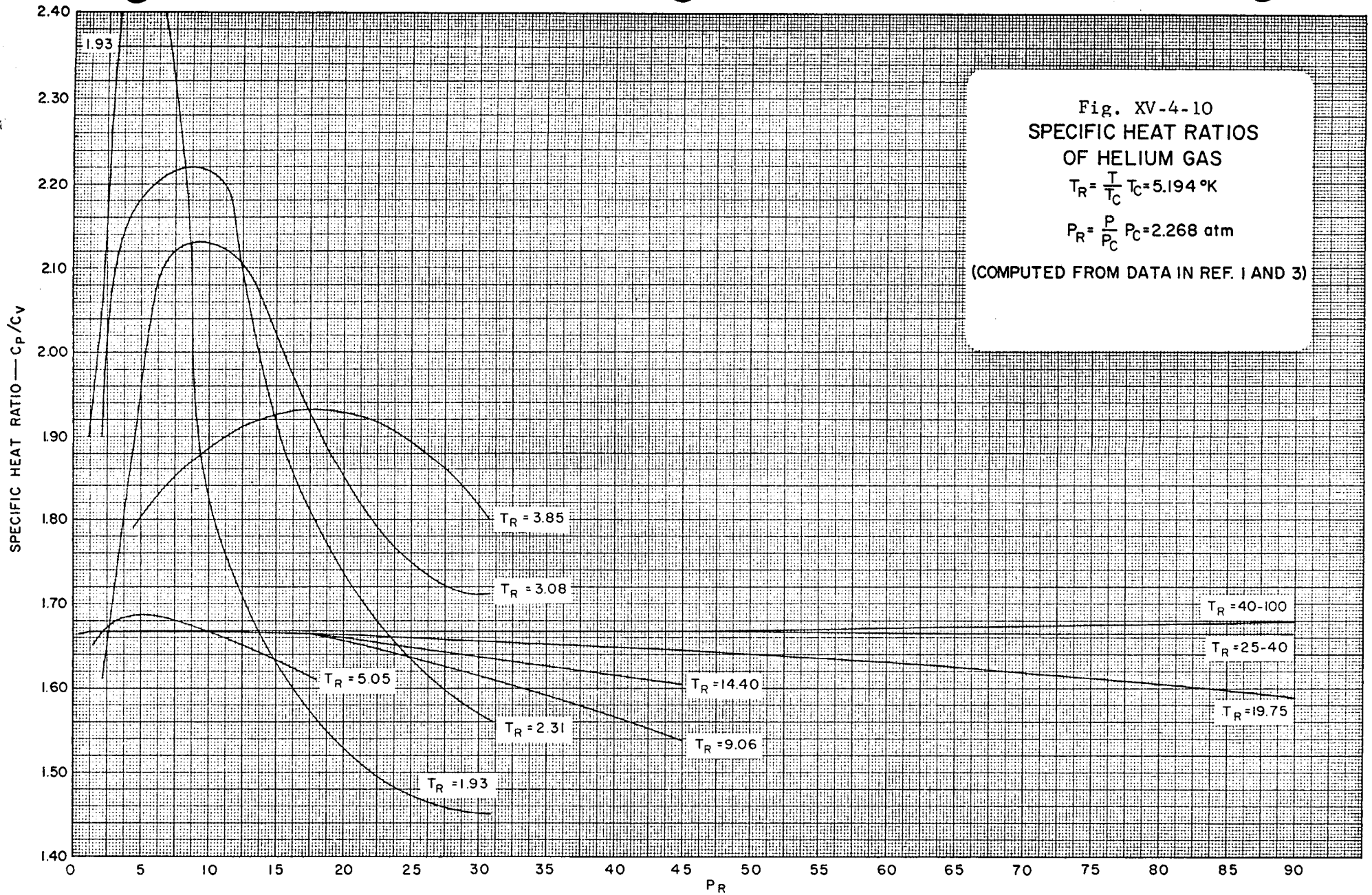


Fig. XV-4-10
SPECIFIC HEAT RATIOS
OF HELIUM GAS
$T_R = \frac{T}{T_C}$ T_C=5.194 °K
$P_R = \frac{P}{P_C}$ P_C=2.268 atm
(COMPUTED FROM DATA IN REF. 1 AND 3)
SPECIFIC HEAT RATIO — C_P/C_V
P_R
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
1.93
T_R = 3.85
T_R = 3.08
T_R = 5.05
T_R = 2.31
T_R = 1.93
T_R = 14.40
T_R = 9.06
T_R = 40-100
T_R = 25-40
T_R = 19.75

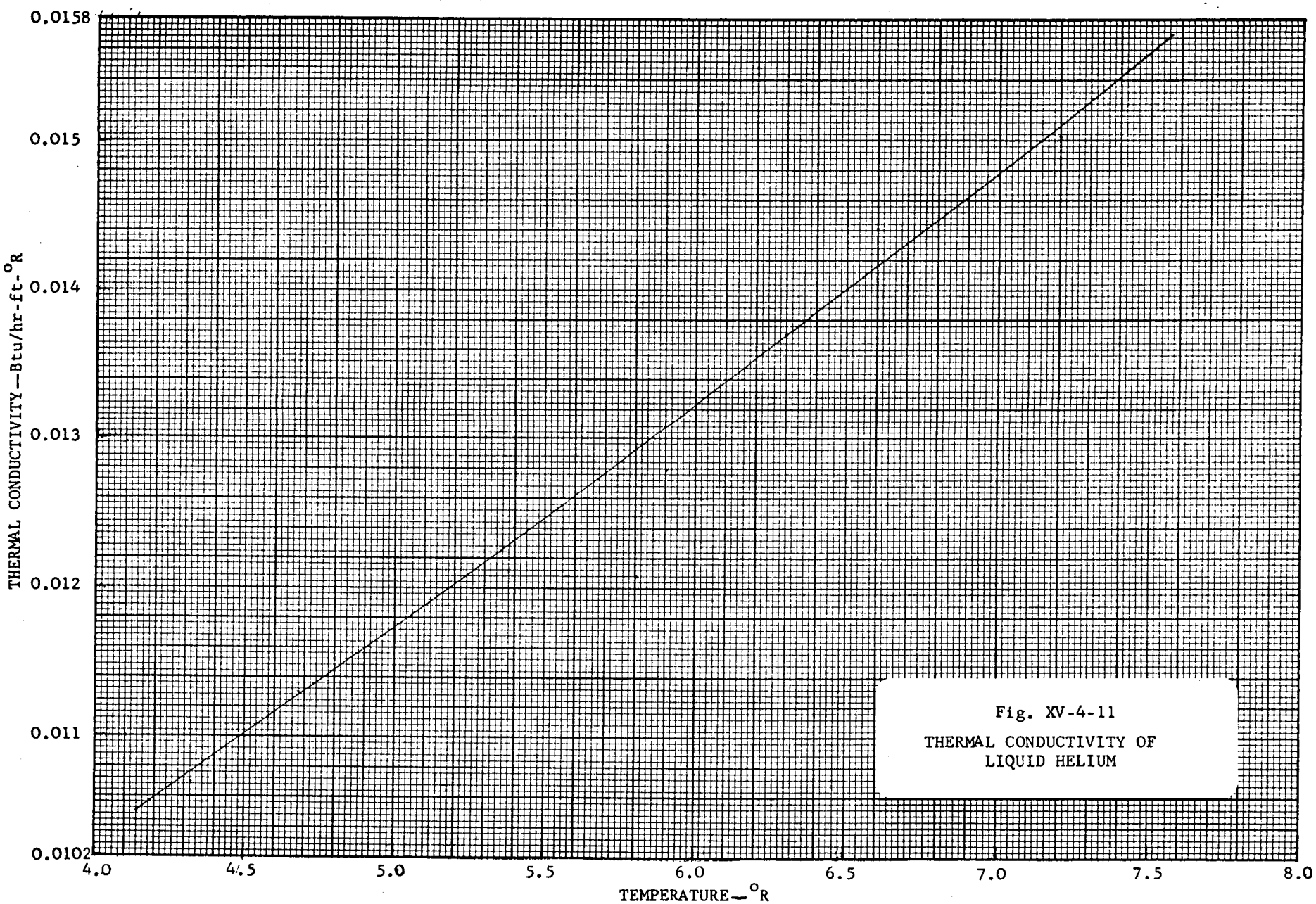


Fig. XV-4-11

THERMAL CONDUCTIVITY OF LIQUID HELIUM

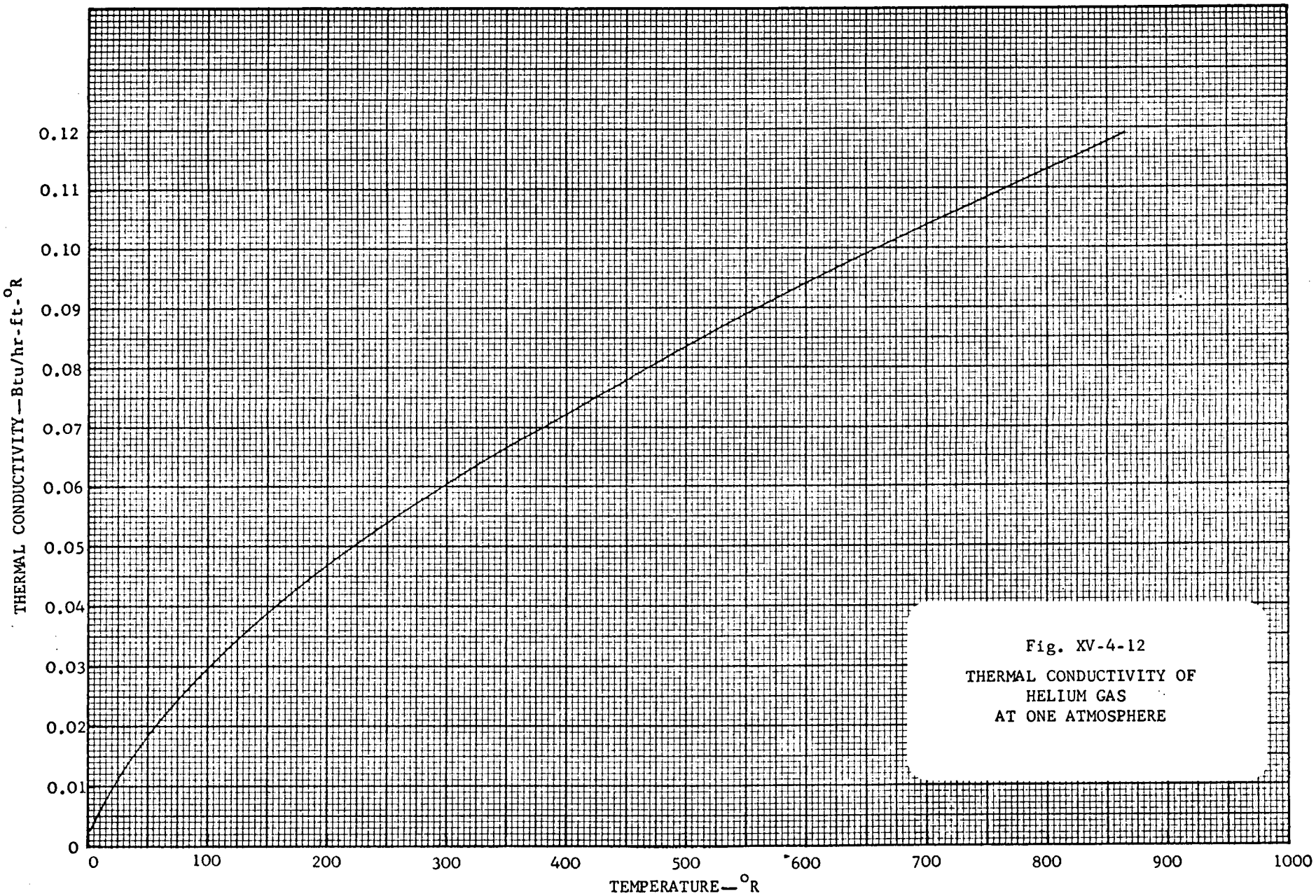


Fig. XV-4-12

THERMAL CONDUCTIVITY OF HELIUM GAS AT ONE ATMOSPHERE

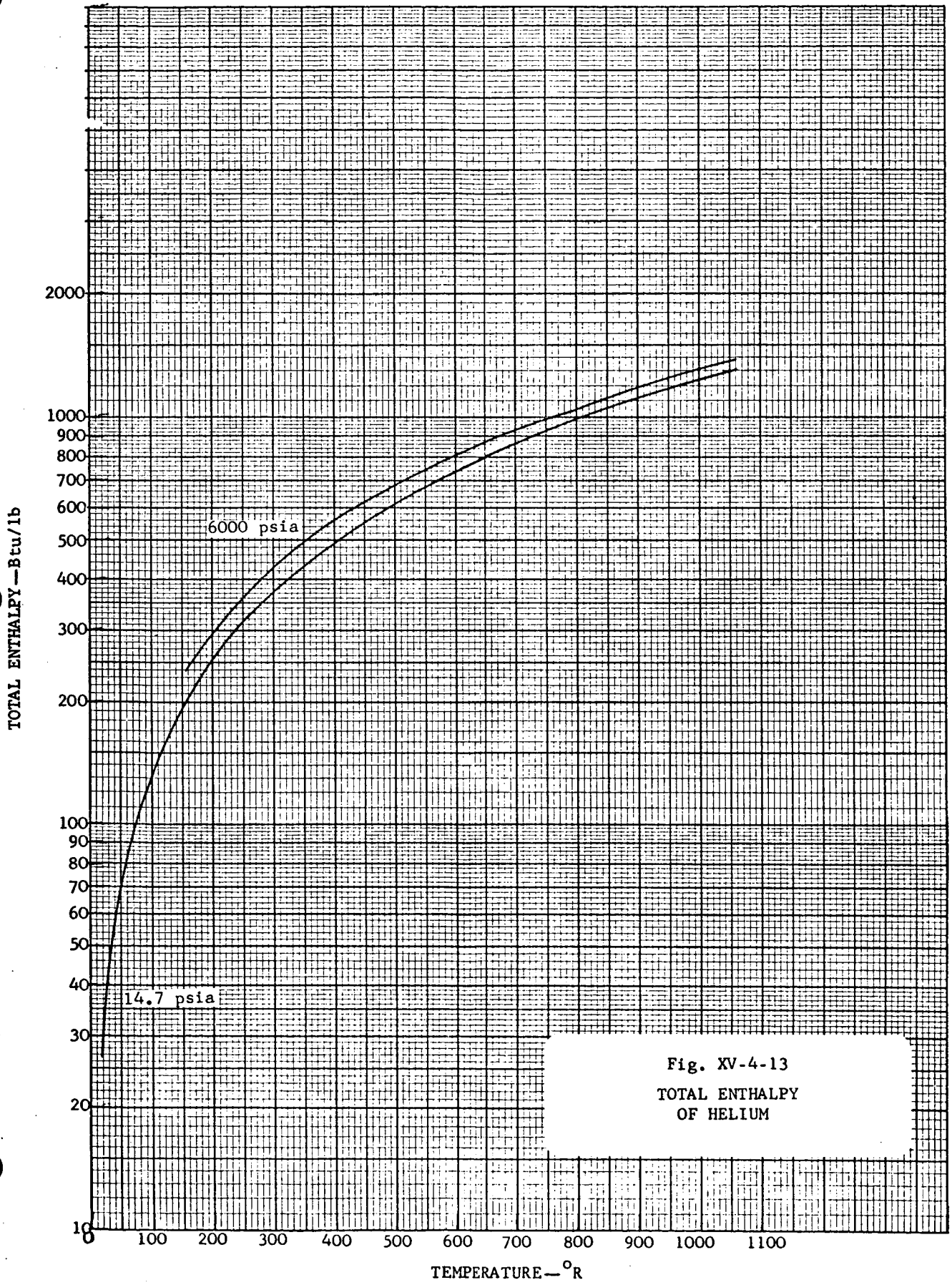


Fig. XV-4-13

TOTAL ENTHALPY
OF HELIUM

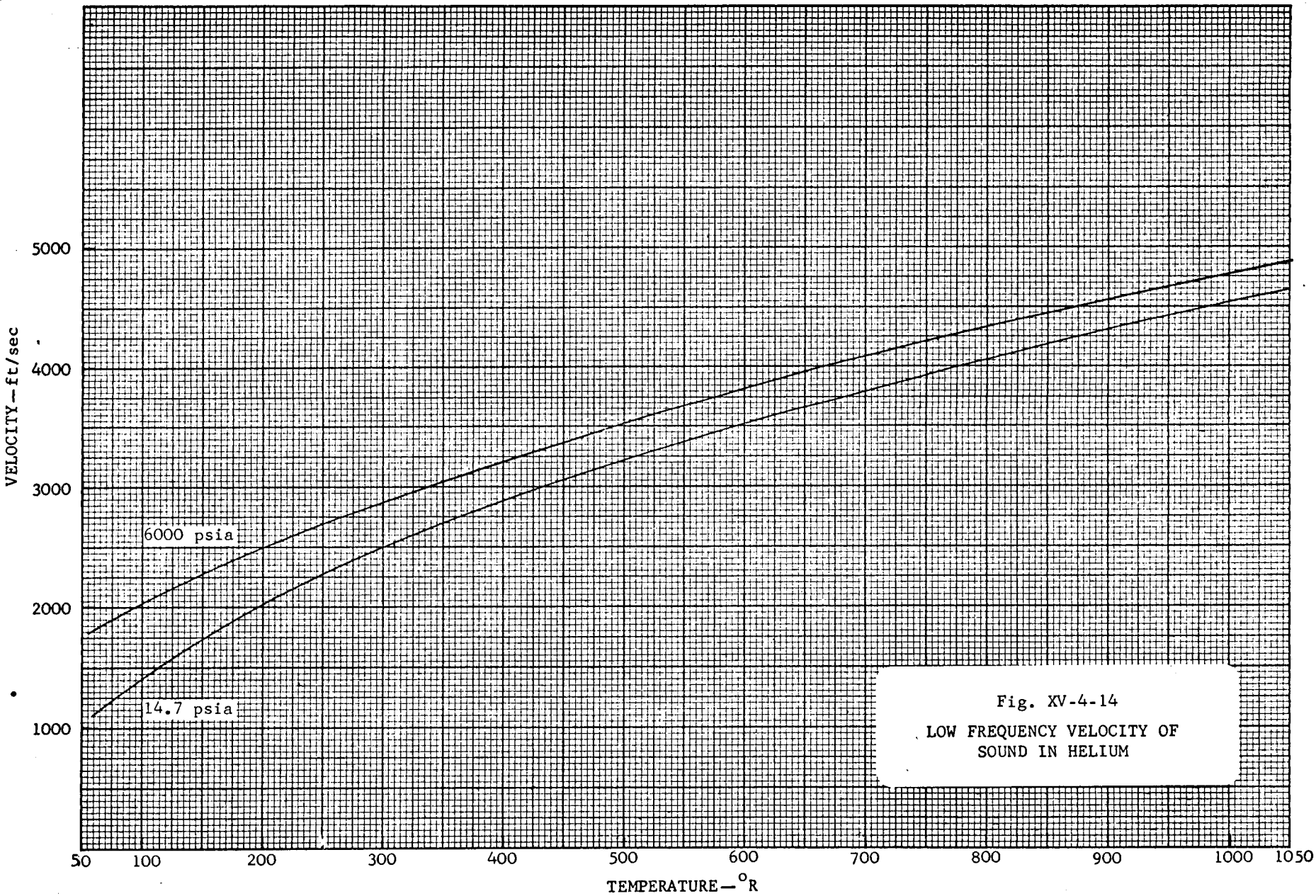


Fig. XV-4-14

LOW FREQUENCY VELOCITY OF SOUND IN HELIUM

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Table XV-5-1

PHYSICAL CONSTANTS

OF

OXYGEN

		REF.
Molecular Weight	32.00	4
Boiling Point @ 1 atm.	-297.4°F	4
Freezing Point @ 1 atm.	-361.1°F	4
Specific Volume @ 70°F, 1 atm.	12.1 cu-ft/lb	4
Vapor Pressure @ -298°F	14.4 psia	2
Specific Gravity, (Air = 1)	1.1053	4
Density		
Liquid @ b.p.	71.17 lb/cu-ft	6
Gas @ 68°F, 1 atm.	0.0892 lb/cu-ft	4
Critical Temperature	-181.1°F	4
Critical Pressure	736.5 psia	4
Critical Density	25.60 lb/cu-ft	4
Latent Heat of Vaporization @ b.p.	91.80 Btu/lb	4
Latent Heat of Fusion @ m.p.	5.94 Btu/lb	4
Specific Heat of Gas		
c_p @ 59°F, 1 atm.	0.2177 Btu/lb-°F	4
c_v @ 59°F, 1 atm.	0.1554 Btu/lb-°F	4
Specific Heat Ratio, c_p/c_v @ 59°F, 1 atm.	1.401	4
Thermal Conductivity @ 32°F	0.0142 Btu/hr-ft-°F	4
Viscosity		
Liquid @ -297.4°F	1.27×10^{-4} lb/ft-sec	6
Gas @ 68°F	1.38×10^{-5} lb/ft-sec	4
Solubility in Water @ 32°F	1 volume/32 volumes	4
Surface Tension @ -297.4°F	9.045×10^{-4} lb/ft	6

Table XV-5-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR MOLECULAR OXYGEN
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.56427	2.64947	1948.84	37.6845
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0410753	0.0424401	31.2172	0.603643
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.42459	1.47193	1082.69	20.9358
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0228196	0.0235778	17.3429	0.335357
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-5-2

VAPOR PRESSURE OF LIQUID OXYGEN
(Ref. 2)

TEMPERATURE		VAPOR PRESSURE	
°K	°R	atm	psia
55	99	0.00182	0.027
60	108	0.00716	0.105
65	117	0.0229	0.34
70	126	0.0616	0.90
75	135	0.1430	2.10
80	144	0.2964	4.36
85	153	0.5597	8.23
90	162	0.9803	14.41
95	171	1.6096	23.65
100	180	2.5066	36.84
105	189	3.7345	54.88
110	198	5.3591	78.76
115	207	7.4495	109.48
120	216	10.077	148.09
125	225	13.316	195.70
130	234	17.239	253.40
135	243	21.934	322.30
140	252	27.489	404.00
145	261	34.004	499.70
150	270	41.620	611.60

(See Figure XV-5-1)

Table XV-5-3

VAPOR PRESSURE OF SOLID OXYGEN (Ref. 5)

TEMPERATURE		VAPOR PRESSURE	
^{o}K	^{o}R	psia	atm
37.3	66.98	3.52×10^{-5}	2.39×10^{-6}
39.0	69.98	8.51×10^{-5}	5.79×10^{-6}
43.1	77.38	1.93×10^{-4}	1.32×10^{-5}
44.1	79.18	4.25×10^{-4}	2.90×10^{-5}
46.0	82.58	8.70×10^{-4}	5.92×10^{-5}
50.7	91.08	5.63×10^{-3}	3.83×10^{-4}
54.3	97.58	2.32×10^{-2}	1.58×10^{-3}

(See Figure XV-5-2)

Table XV-5-4

DENSITY OF LIQUID OXYGEN
(Ref. 3)

TEMPERATURE		DENSITY
^{o}K	^{o}R	lb/ft^3
61	109.8	80.035
65	117.0	78.85
70	126.0	77.35
80	144.0	74.35
85	153.0	72.86
90	162.0	71.30
118.6	213.48	60.92
132.9	239.22	54.58
143.2	257.76	48.58
149.8	269.64	42.32
152.7	274.86	37.66

Table XV-5-5

DENSITY OF OXYGEN (Ref. 7, 8, 9)

DENSITY-lb/ft^3							
PRESSURE psia \ TEMP. °R	200	300	400	500	600	700	800
100	64.2	1.0	0.7	0.6	0.45	0.40	0.33
500	64.8	6.4	4.0	3.0	2.45	2.15	1.83
1000	65.4	21.0	8.7	6.3	5.00	4.19	3.57
2000	66.9	44.9	19.5	12.7	9.91	8.28	7.10
3000	68.0	50.2	29.1	19.4	14.59	11.91	10.28
4000	69.0	53.0	35.8	24.8	19.43	15.60	13.24
5000	69.9	55.2	40.5	29.6	23.18	19.38	16.32
6000	70.8	56.9	44.0	33.5	26.70	22.28	19.31

(See Figure XV-5-3)

Table XV-5-6

SURFACE TENSION OF LIQUID OXYGEN (Ref. 12)

TEMPERATURE		SURFACE TENSION
^{o}K	^{o}R	$lb/ft x 10^{-3}$
70	126.0	1.257
71	127.8	1.240
72	129.6	1.221
73	131.4	1.203
74	133.2	1.185
75	135.0	1.167
76	136.8	1.148
77	138.6	1.131
78	140.4	1.113
79	142.2	1.096
80	144.0	1.078
81	145.8	1.060
82	147.6	1.044
83	149.4	1.026
84	151.2	1.009
85	153.0	0.991
86	154.8	0.974
87	156.6	0.957
88	158.4	0.940
89	160.2	0.923
90	162.0	0.907

(See Figure XV-5-4)

Table XV-5-7

VISCOSITY OF LIQUID OXYGEN (Ref. 3)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises	°K	°R	centipoises
54.4	97.92	0.873	68.9	124.02	0.377
54.5	98.10	0.863	72.3	130.14	0.323
54.6	98.28	0.821	77.4	139.32	0.273
54.9	98.82	0.772	80.0	144.0	0.250
56.4	101.52	0.717	90.0	162.0	0.190
57.4	103.32	0.648	111.0	199.80	0.123
59.7	107.46	0.631	125.8	226.44	0.110
61.7	111.06	0.521	138.2	248.76	0.100
63.5	114.30	0.476	145.5	261.90	0.098
65.4	117.72	0.435	154.1	277.38	0.090

(See Figure XV-5-5)

Table XV-5-8

VISCOSITY OF GASEOUS OXYGEN (Ref. 2)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	micropoises	°K	°R	micropoises
100	180	77.73	320	576	216.75
120	216	93.06	340	612	226.81
140	252	107.86	360	648	236.66
160	288	122.04	380	684	246.23
180	324	135.67	400	720	255.56
200	360	148.60	420	756	264.68
220	396	161.06	440	792	273.58
240	432	173.04	460	828	282.31
260	468	184.57	480	864	290.89
280	504	195.64	500	900	299.30
300	540	206.33			

(See Figure XV-5-6)

Table XV-5-9

HEAT CAPACITY OF LIQUID OXYGEN (Ref. 10)

TEMPERATURE		HEAT CAPACITY (C_p)
^oF	^oR	Btu/lb-^oR
-357.2	102.5	0.3988
-355.4	104.3	0.3975
-350.0	109.7	0.3972
-349.0	110.7	0.3972
-341.7	118.0	0.3972
-341.0	118.7	0.3972
-335.9	123.8	0.3978
-335.3	124.4	0.3984
-332.5	127.2	0.3991
-331.2	128.5	0.3994
-327.7	132.0	0.4003
-324.8	134.9	0.4016
-323.2	136.5	0.4000
-320.1	139.6	0.4013
-318.1	141.6	0.4009
-313.7	146.0	0.4025
-311.5	148.2	0.4019
-310.4	149.3	0.4025
-307.1	152.6	0.4041
-304.1	155.6	0.4034
-303.8	155.9	0.4047
-303.2	156.5	0.4038
-302.5	157.2	0.4034
-297.1	162.6	0.4059

(See Figure XV-5-7)

Table XV-5-10

HEAT CAPACITIES OF OXYGEN (Ref. 2)

TEMPERATURE		HEAT CAPACITY, C_p--Btu/lb-°R		
°K	°R	1 atm	10 atm	100 atm
120	216	0.2213		
140	252	0.2198		
160	288	0.2190	0.2387	
180	324	0.2186	0.2317	
200	360	0.2184	0.2280	0.471
220	396	0.2183	0.2257	0.357
240	432	0.2184	0.2243	0.307
260	468	0.2187	0.2235	0.2816
280	504	0.2191	0.2231	0.2673
300	540	0.2197	0.2231	0.2585
320	576	0.2205	0.2234	0.2527
340	612	0.2214	0.2239	0.2488
360	648	0.2225	0.2247	0.2462
380	684	0.2236	0.2256	0.2444
400	720	0.2249	0.2266	0.2433
420	756	0.2263	0.2278	0.2427
440	792	0.2277	0.2291	0.2425
460	828	0.2292	0.2301	0.2425
480	864	0.2307	0.2318	0.2428
500	900	0.2322	0.2332	0.2433

(See Figure XV-5-8)

Table XV-5-11

THERMAL CONDUCTIVITY OF GASEOUS OXYGEN (Ref. 1)

TEMPERATURE		THERMAL CONDUCTIVITY--Btu/hr-ft-°R				
°K	°R	1 atm	10 atm	50 atm	100 atm	140 atm
80	144				0.0968	0.0996
100	180	0.0050			0.0838	0.0870
120	216	0.0060	0.0076	0.0644	0.0692	0.0724
140	252	0.0072	0.0084	0.0508	0.0542	0.0582
160	288	0.0082	0.0092	0.0168	0.0392	0.0450
180	324	0.0092	0.0102	0.0128	0.0271	0.0346
200	360	0.0104	0.0112	0.0126	0.0193	0.0268
220	396	0.0114	0.0120	0.0130	0.0159	
240	432	0.0126	0.0130	0.0136	0.0148	
260	468	0.0136	0.0140	0.0144	0.0150	
280	504	0.0147	0.0150	0.0152	0.0154	
300	540	0.0159	0.0159	0.0159	0.0159	

(See Figure XV-5-10)

Table XV-5-12

THERMAL CONDUCTIVITY
OF LIQUID OXYGEN
AT SATURATION PRESSURE
(Ref. 11)

TEMPERATURE		THERMAL CONDUCTIVITY
^{o}K	^{o}R	Btu/hr-ft-^{o}R
80	144	0.009425
85	153	0.009078
90	162	0.008673
95	171	0.008326
100	180	0.007864

Table XV-5-13

HEAT OF VAPORIZATION OF
LIQUID OXYGEN (Ref. 3)

TEMPERATURE		LATENT HEAT
^{o}K	^{o}R	Btu/lb
69	124.2	99.58
70	126.0	99.25
72	129.6	98.60
74	133.2	97.92
76	136.8	97.25
78	140.4	96.57
80	144.0	95.85
82	147.6	95.10
84	151.2	94.31
86	154.8	93.45
88	158.4	92.50
90	162.0	91.44

(See Figure XV-5-11)

Table XV-5-14

TOTAL ENTHALPY OF OXYGEN (Ref. 2)

TEMPERATURE		TOTAL ENTHALPY-Btu/lb			
°K	°R	0.01 atm	1.0 atm	10 atm	100 atm
100	180	77.944	76.530		
120	216	93.586	92.609		
140	252	109.24	108.48		
160	288	124.88	124.26	118.33	
180	324	140.53	140.02	135.24	
200	360	156.18	155.76	151.78	101.24
220	396	171.83	171.47	168.10	130.48
240	432	187.51	187.20	184.30	154.16
260	468	203.21	202.93	200.42	175.27
280	504	218.94	218.69	216.49	194.98
300	540	234.71	234.49	232.56	213.90
320	576	250.52	250.33	248.63	232.27
340	612	266.41	266.24	264.73	250.27
360	648	282.37	282.22	280.87	268.15
380	684	298.41	298.28	297.08	285.79
400	720	314.55	314.43	313.37	303.37
420	756	330.77	330.67	329.72	320.82
440	792	347.11	347.01	346.17	338.27
460	828	363.55	363.46	362.72	355.79
480	864	380.09	380.02	379.36	373.24
500	900	396.75	396.68	396.10	390.76

(See Figure XV-5-12)

Table XV-5-15

LOW FREQUENCY VELOCITY OF SOUND IN OXYGEN (Ref. 2)

TEMPERATURE		VELOCITY—Ft/sec			
°K	°R	0.01 atm	1 atm	10 atm	100 atm
100	180	626.			
120	216	686.	681.		
140	252	741.	736.		
160	288	791.	789.	767.	
180	324	840.	838.	823.	
200	360	885.	884.	874.	
220	396	928.	928.	921.	941.
240	432	969.	969.	965.	987.
260	468	1008.	1008.	1006.	1033.
280	504	1045.	1045.	1046.	1076.
300	540	1082.	1081.	1082.	1119.
320	576	1117.	1117.	1119.	1159.
340	612	1150.	1151.	1153.	1197.
360	648	1183.	1183.	1186.	1233.
380	684	1214.	1214.	1218.	1267.
400	720	1244.	1244.	1248.	1300.
420	756	1273.	1273.	1278.	1332.
440	792	1301.	1301.	1307.	1362.
460	828	1328.	1329.	1333.	1391.
480	864	1355.	1356.	1361.	1419.
500	900	1382.	1383.	1388.	1447.

(See Figure XV-5-13)

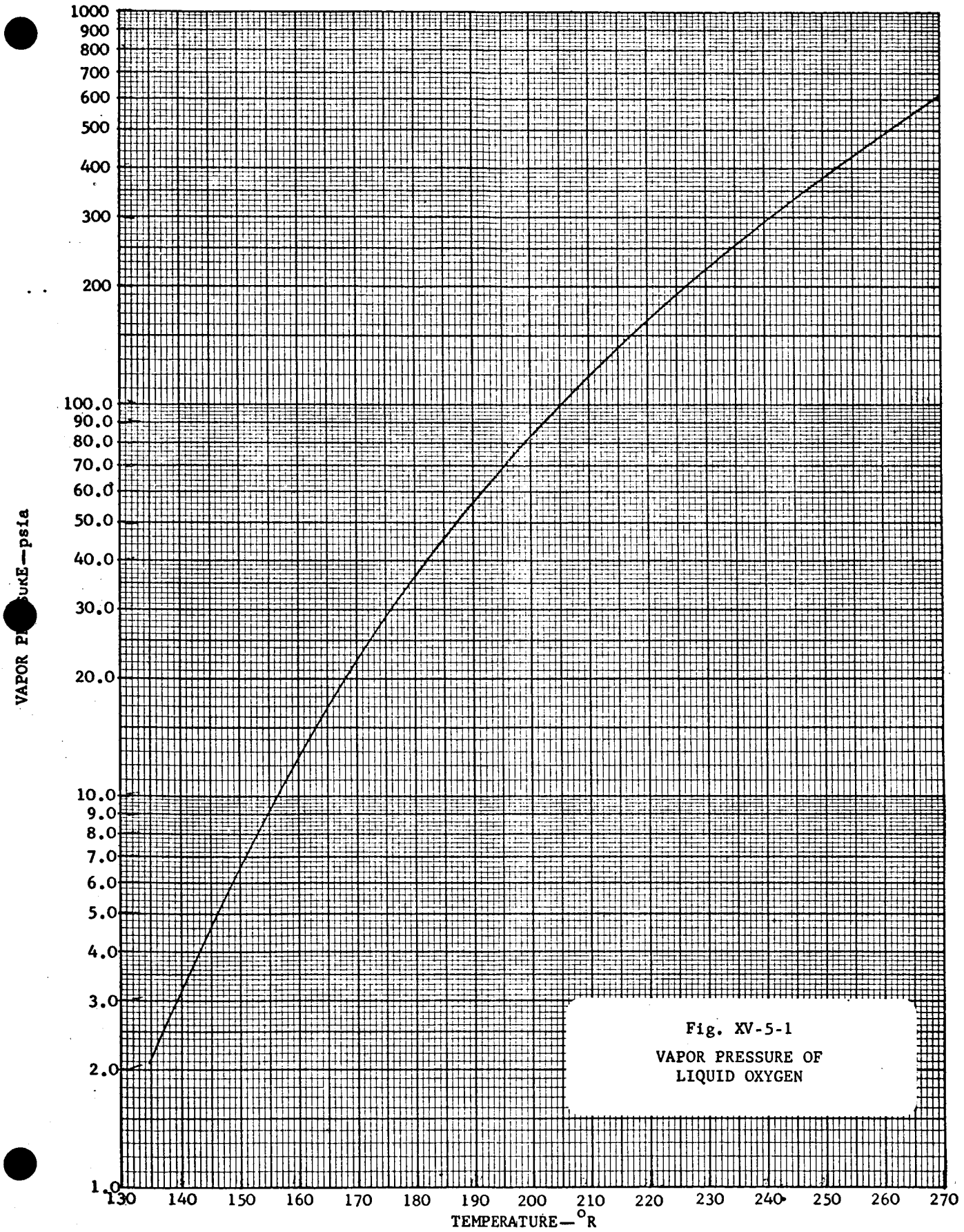


Fig. XV-5-1

VAPOR PRESSURE OF LIQUID OXYGEN

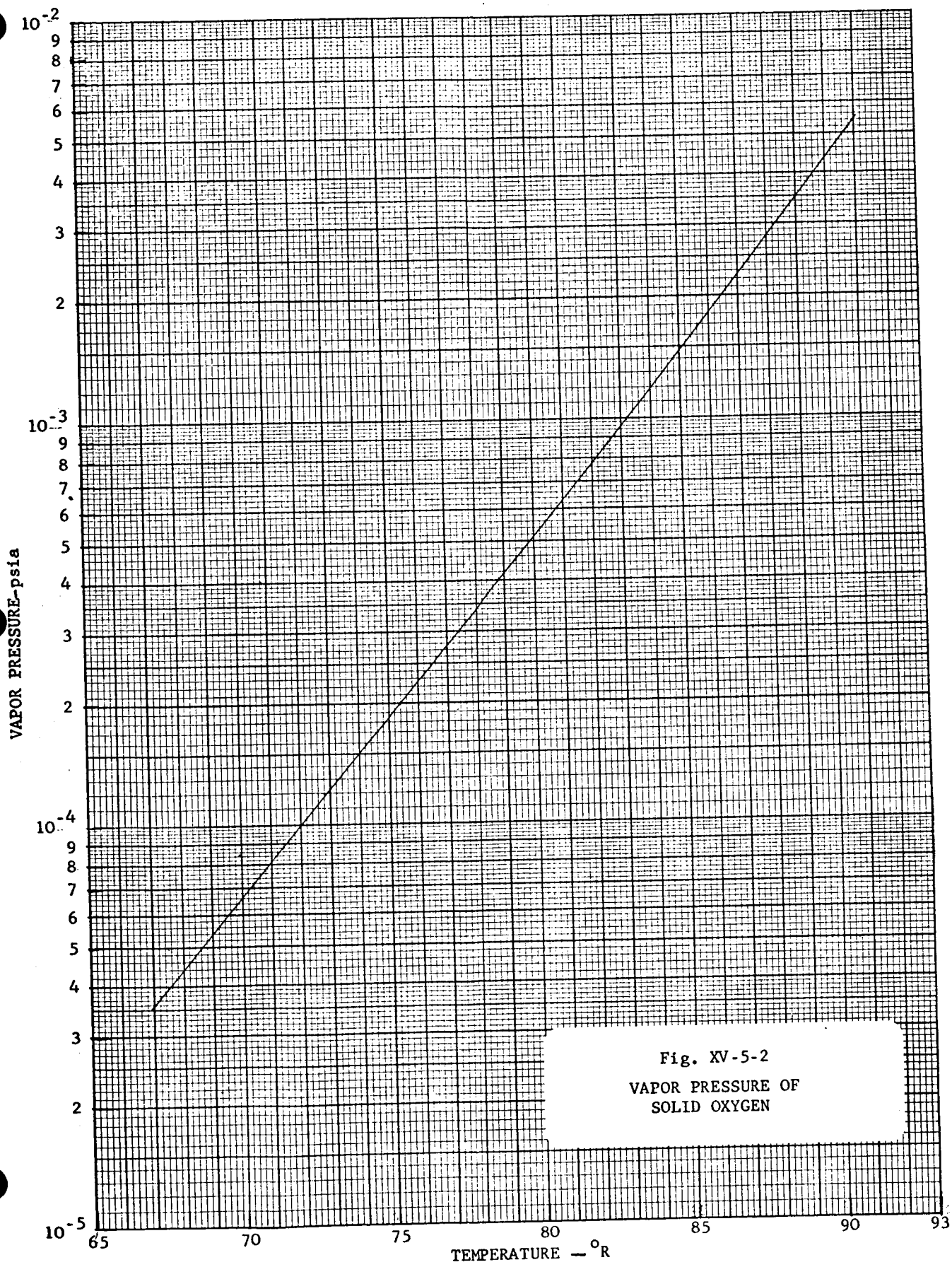
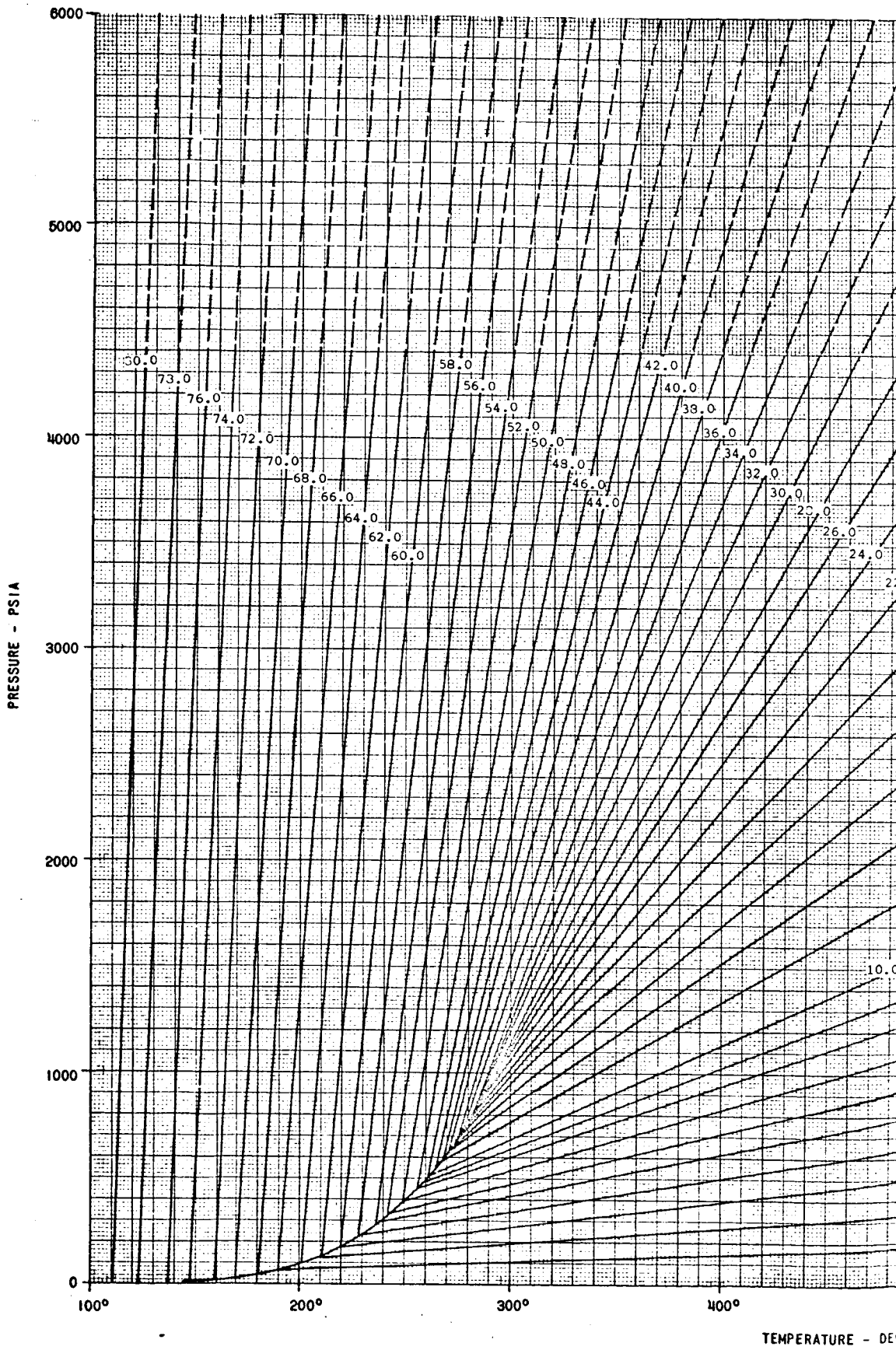


Fig. XV-5-2

VAPOR PRESSURE OF SOLID OXYGEN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5000
4000
3000
2000
1000
0
PRESSURE - PSIA
100°
200°
300°
400°
TEMPERATURE - DE
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74.0
72.0
70.0
68.0
66.0
64.0
62.0
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24.0
10.0

XV-5-3-1

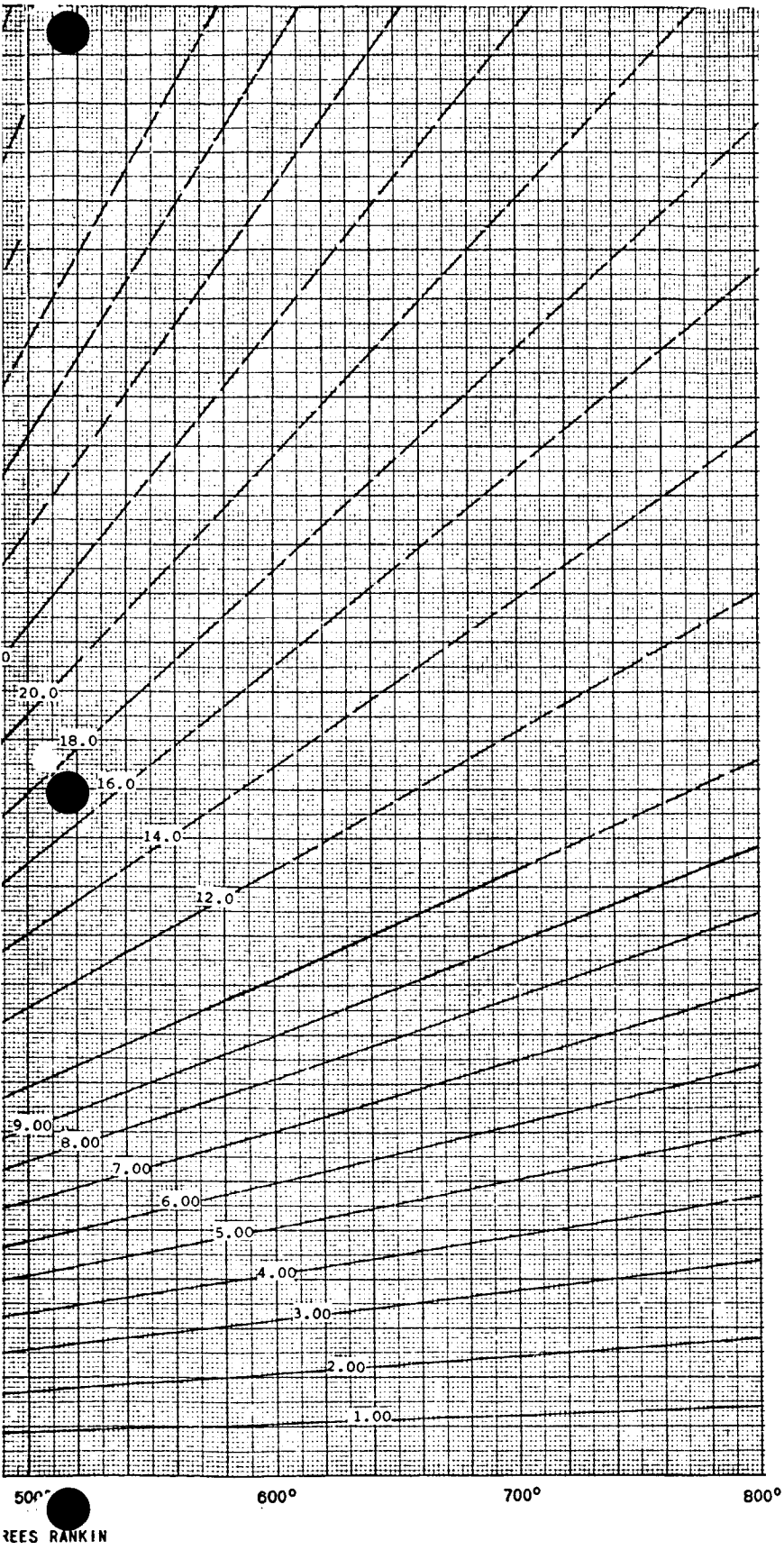

FIG. XV-5-3
OXYGEN (O_2)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

——— COMMONLY ACCEPTED DATA

— — EXTRAPOLATED OR UNCONFIRMED DATA

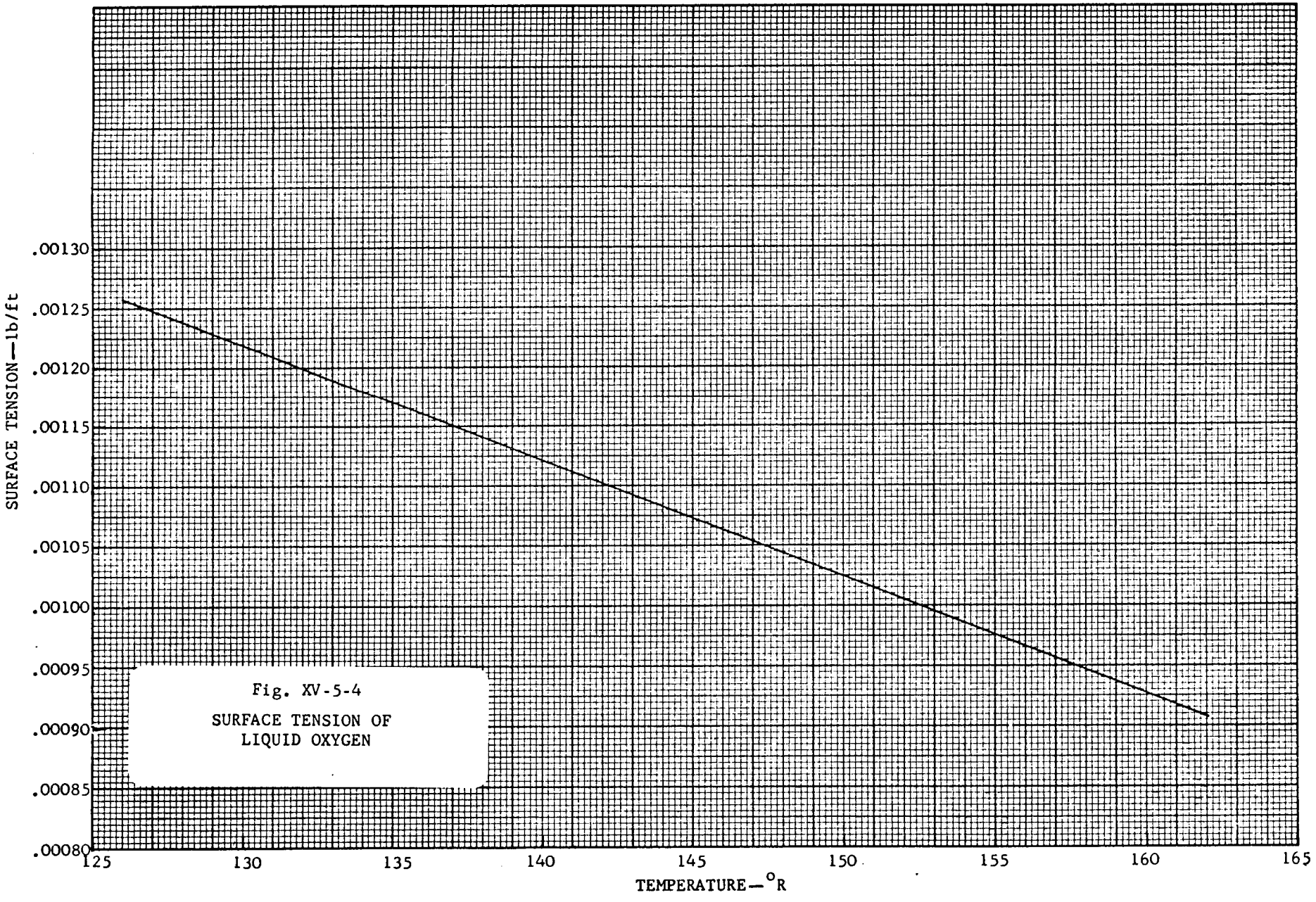

Fig. XV-5-4

SURFACE TENSION OF LIQUID OXYGEN

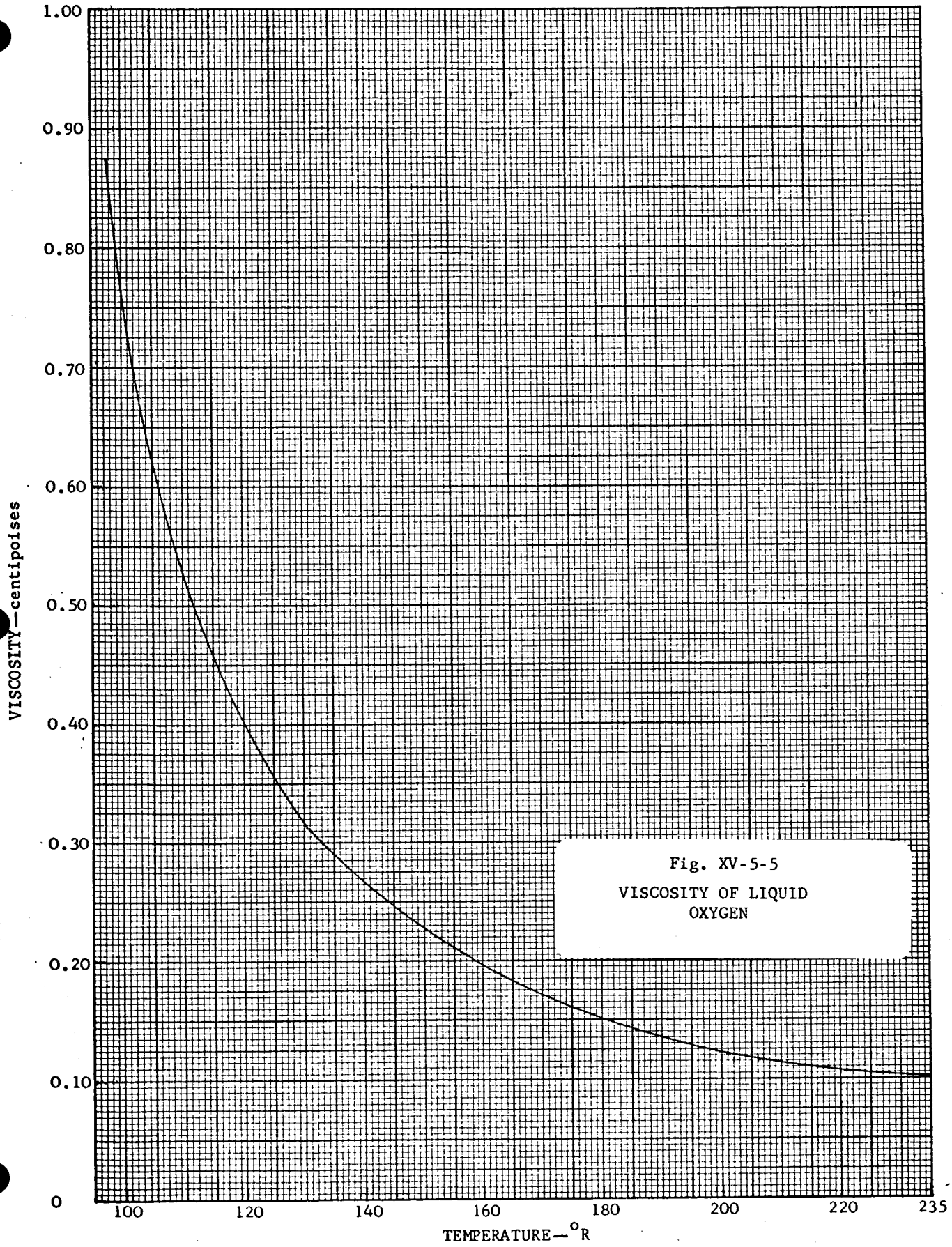

Fig. XV-5-5

VISCOSITY OF LIQUID OXYGEN

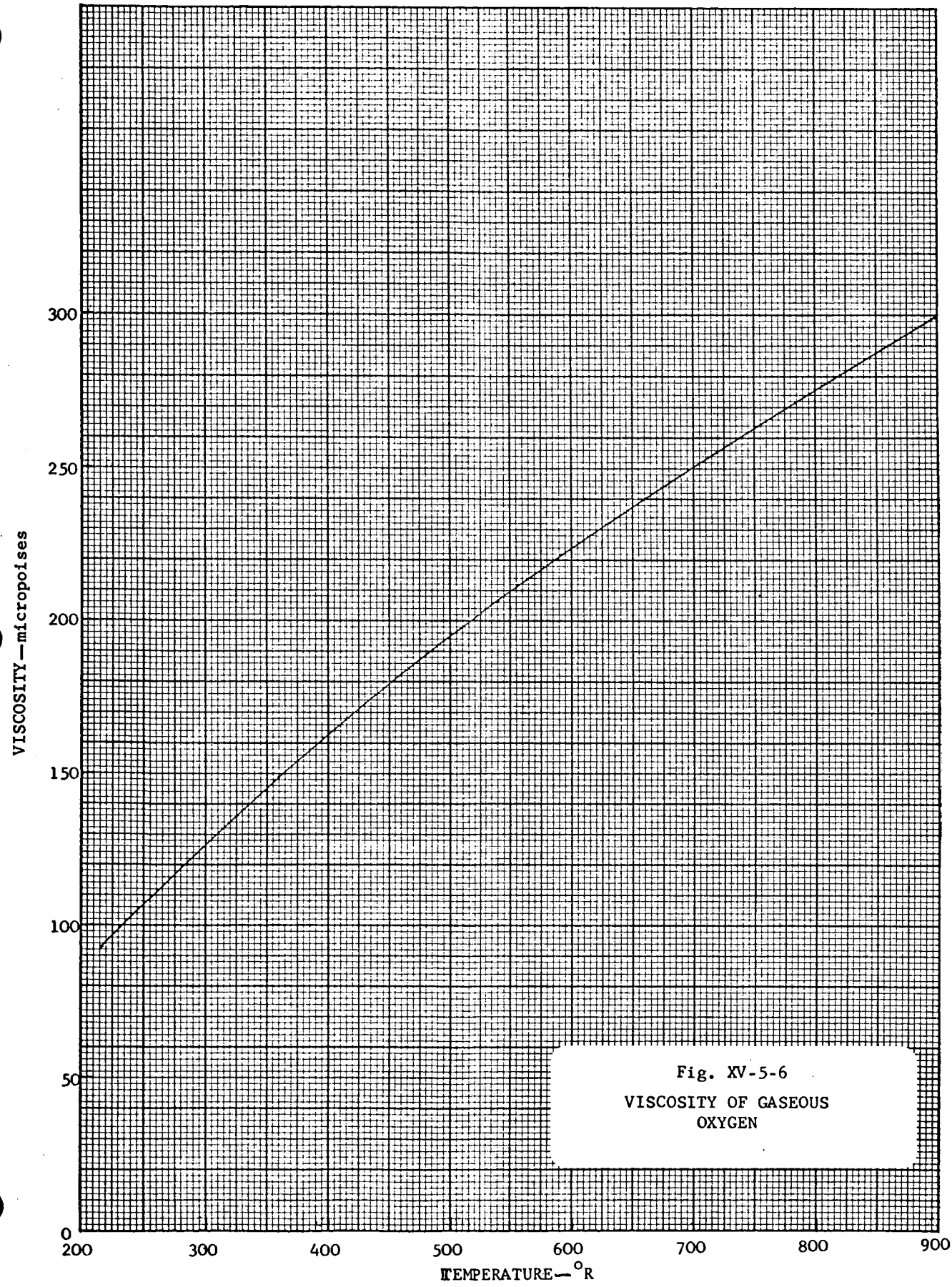

Fig. XV-5-6
VISCOSITY OF GASEOUS OXYGEN

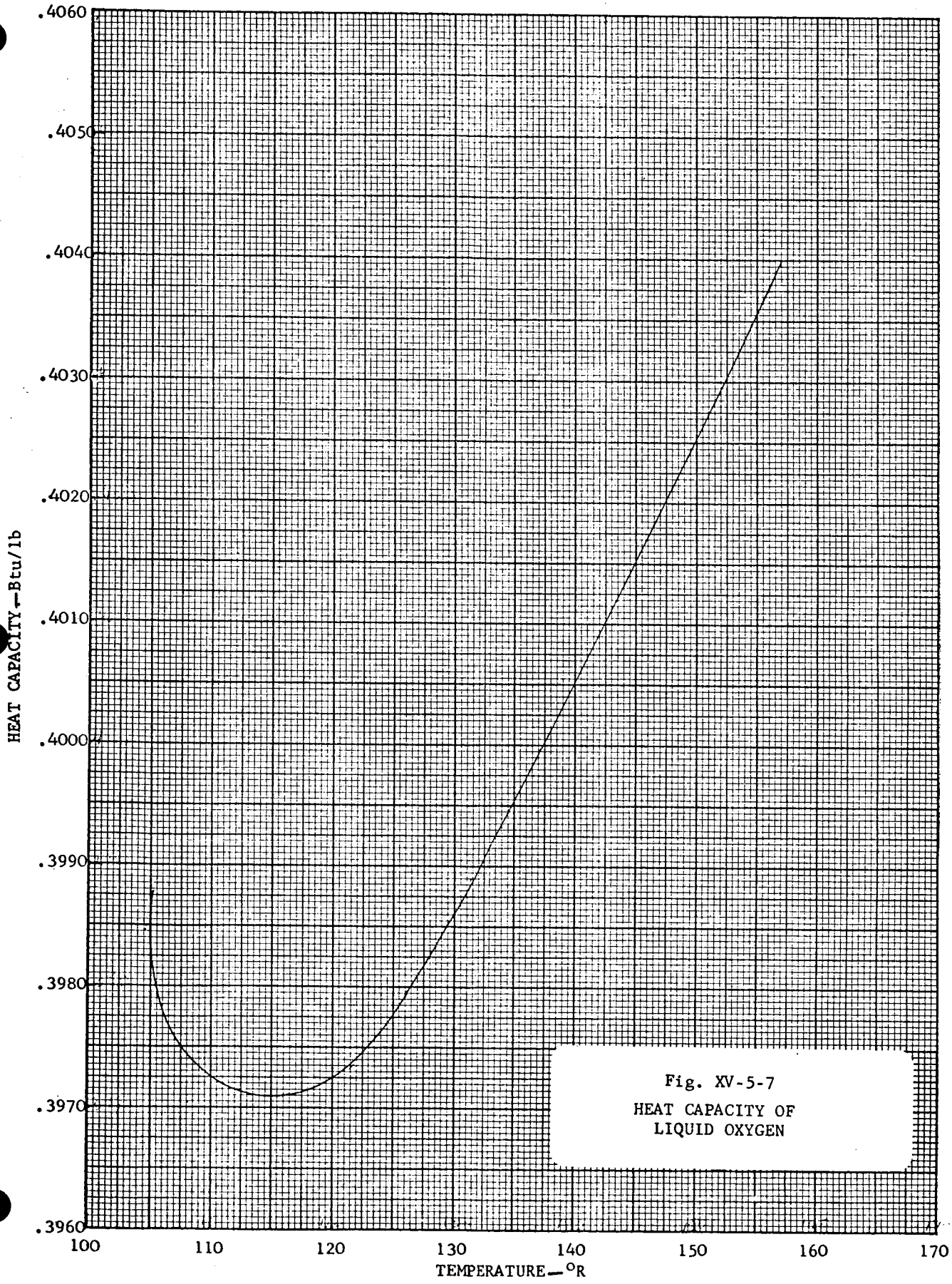

Fig. XV-5-7
HEAT CAPACITY OF
LIQUID OXYGEN

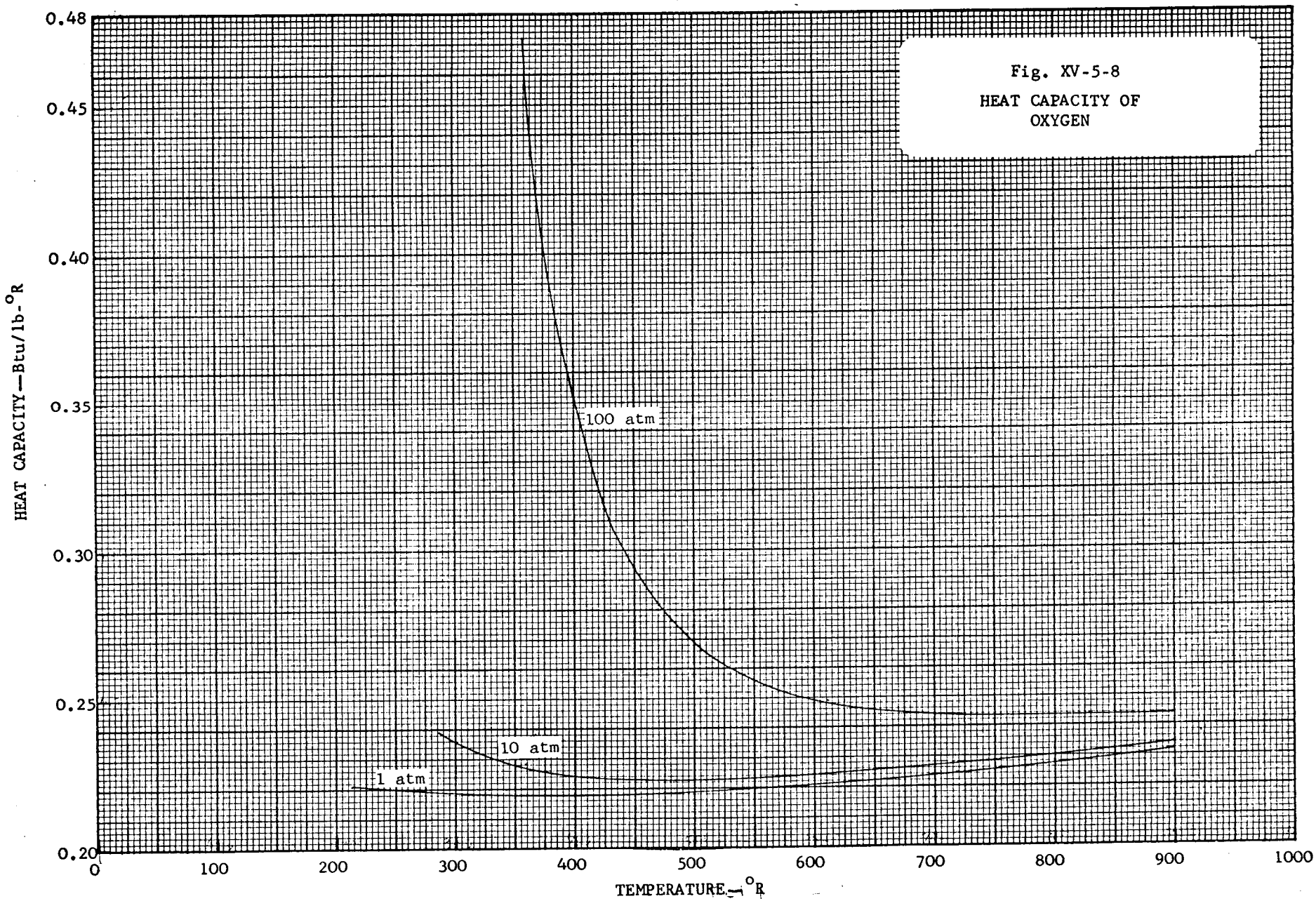

Fig. XV-5-8

HEAT CAPACITY OF OXYGEN

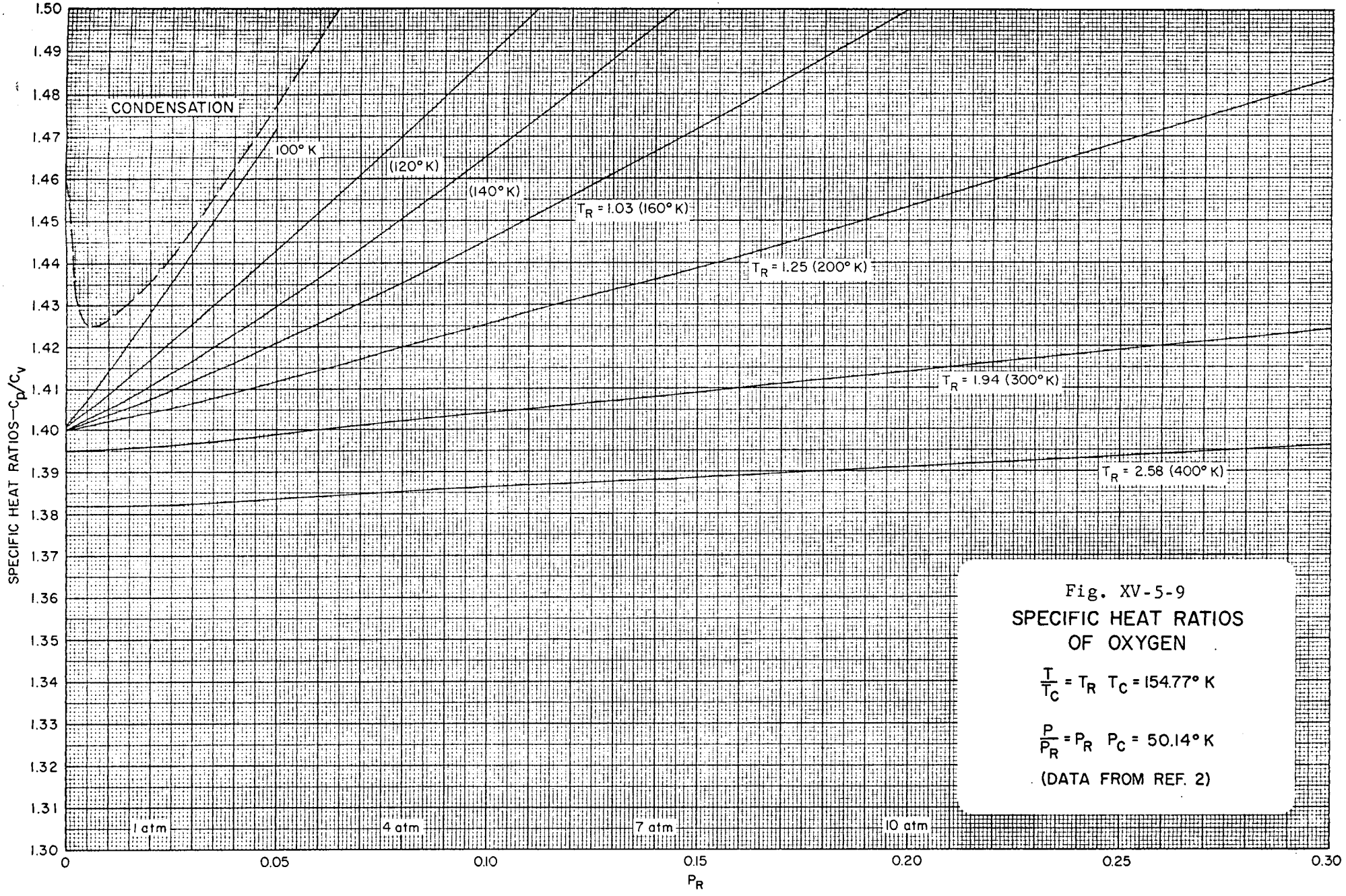

Fig. XV-5-9

SPECIFIC HEAT RATIOS OF OXYGEN

$\frac{T}{T_C} = T_R \quad T_C = 154.77°\ K$

$\frac{P}{P_R} = P_R \quad P_C = 50.14°\ K$

(DATA FROM REF. 2)

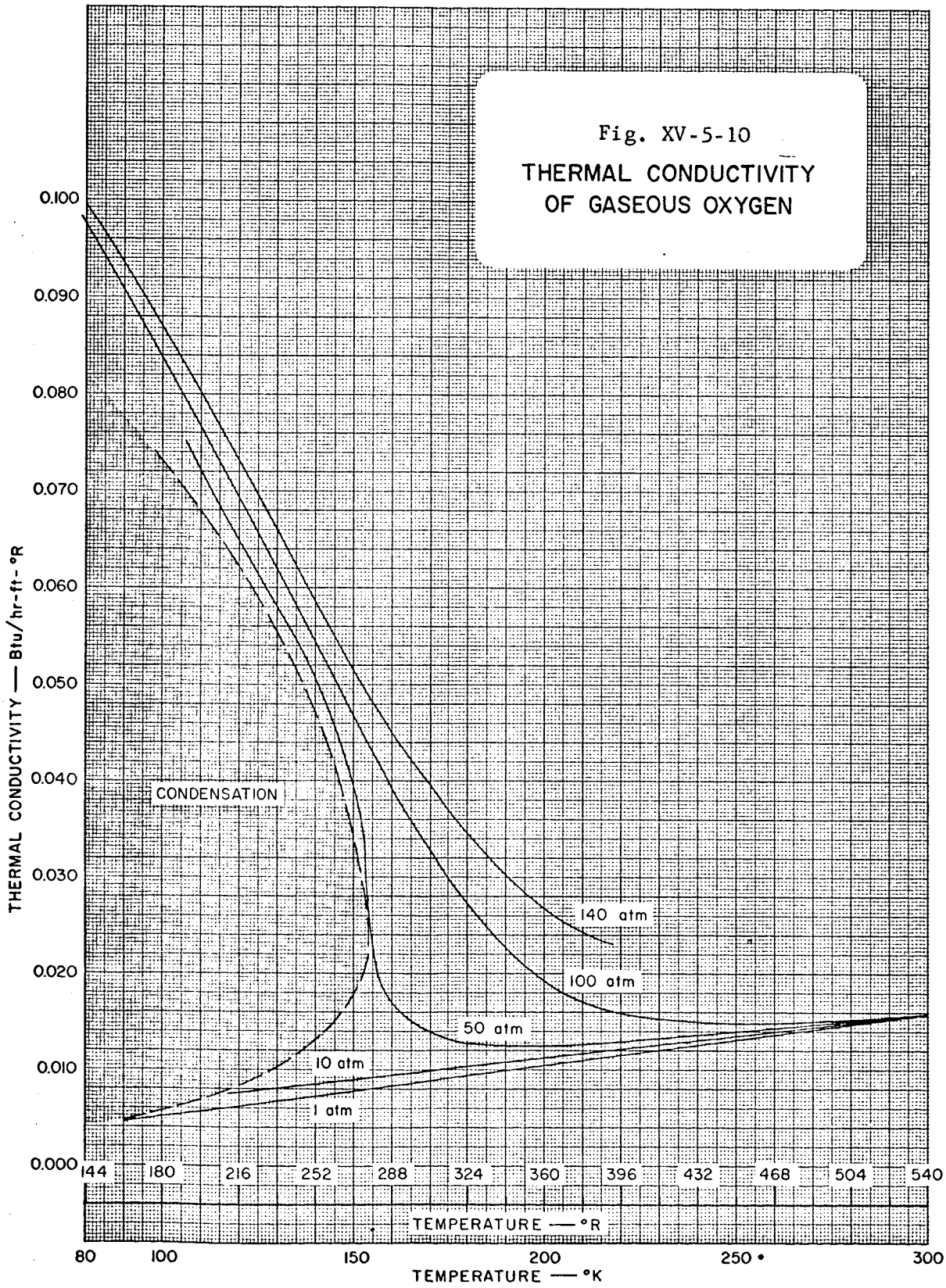
Fig. XV-5-10
THERMAL CONDUCTIVITY
OF GASEOUS OXYGEN
THERMAL CONDUCTIVITY — Btu/hr-ft-°R
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
CONDENSATION
140 atm
100 atm
50 atm
10 atm
1 atm
144
180
216
252
288
324
360
396
432
468
504
540
TEMPERATURE — °R
80
100
150
200
250
300
TEMPERATURE — °K

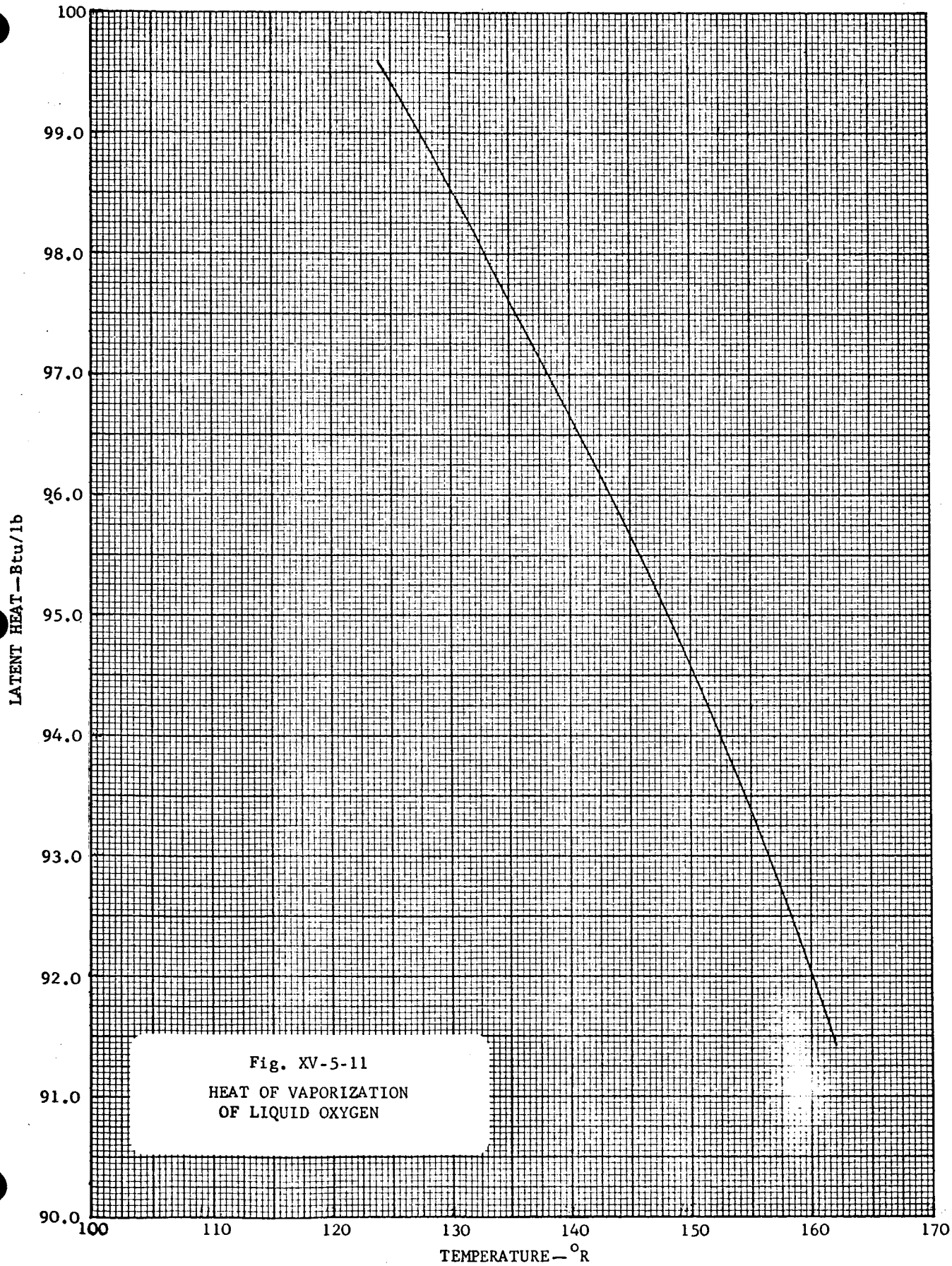

Fig. XV-5-11

HEAT OF VAPORIZATION OF LIQUID OXYGEN

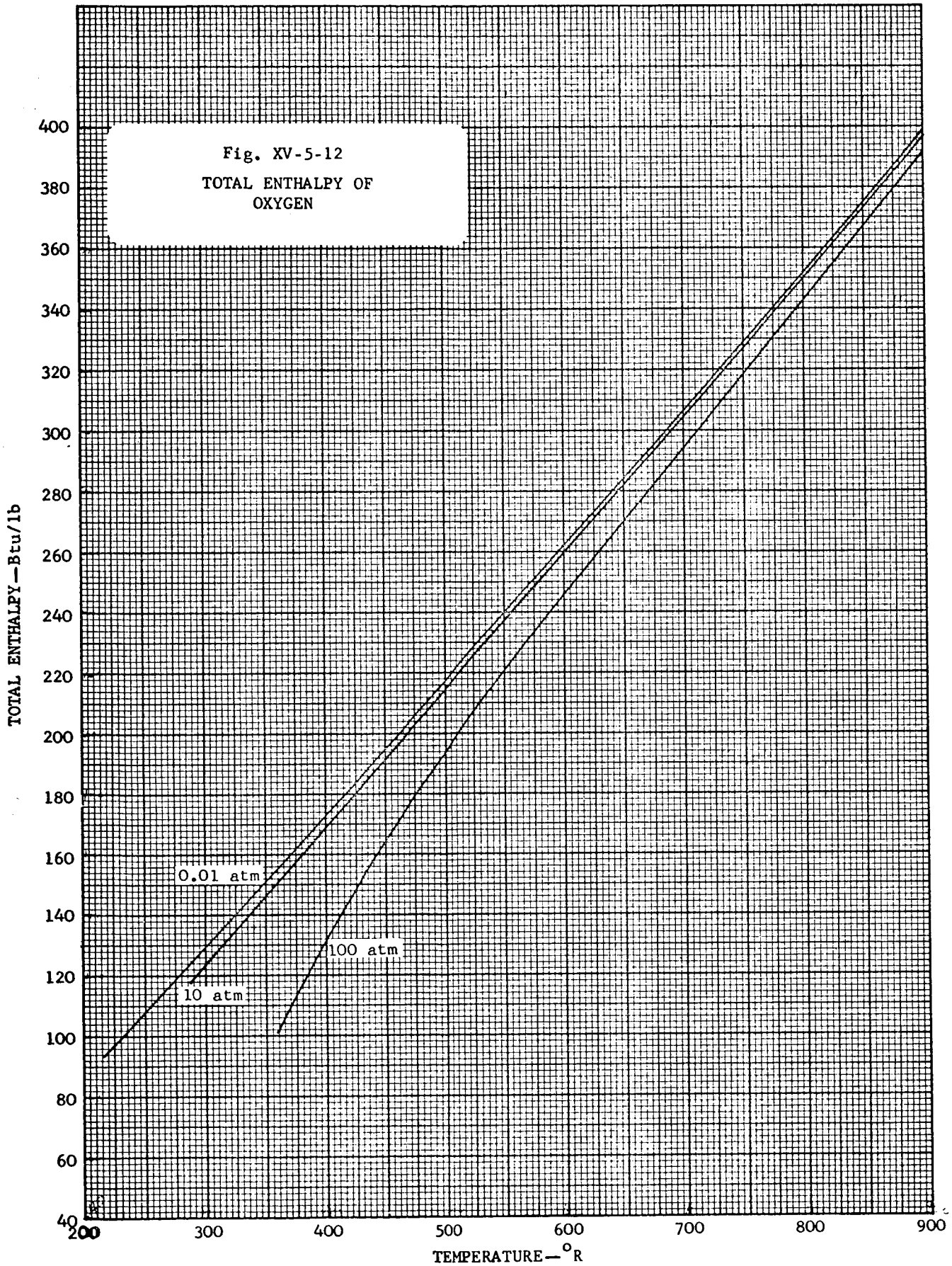
Fig. XV-5-12
TOTAL ENTHALPY OF OXYGEN
TOTAL ENTHALPY—Btu/lb
TEMPERATURE—°R
0.01 atm
10 atm
100 atm
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
200
300
400
500
600
700
800
900

Stop

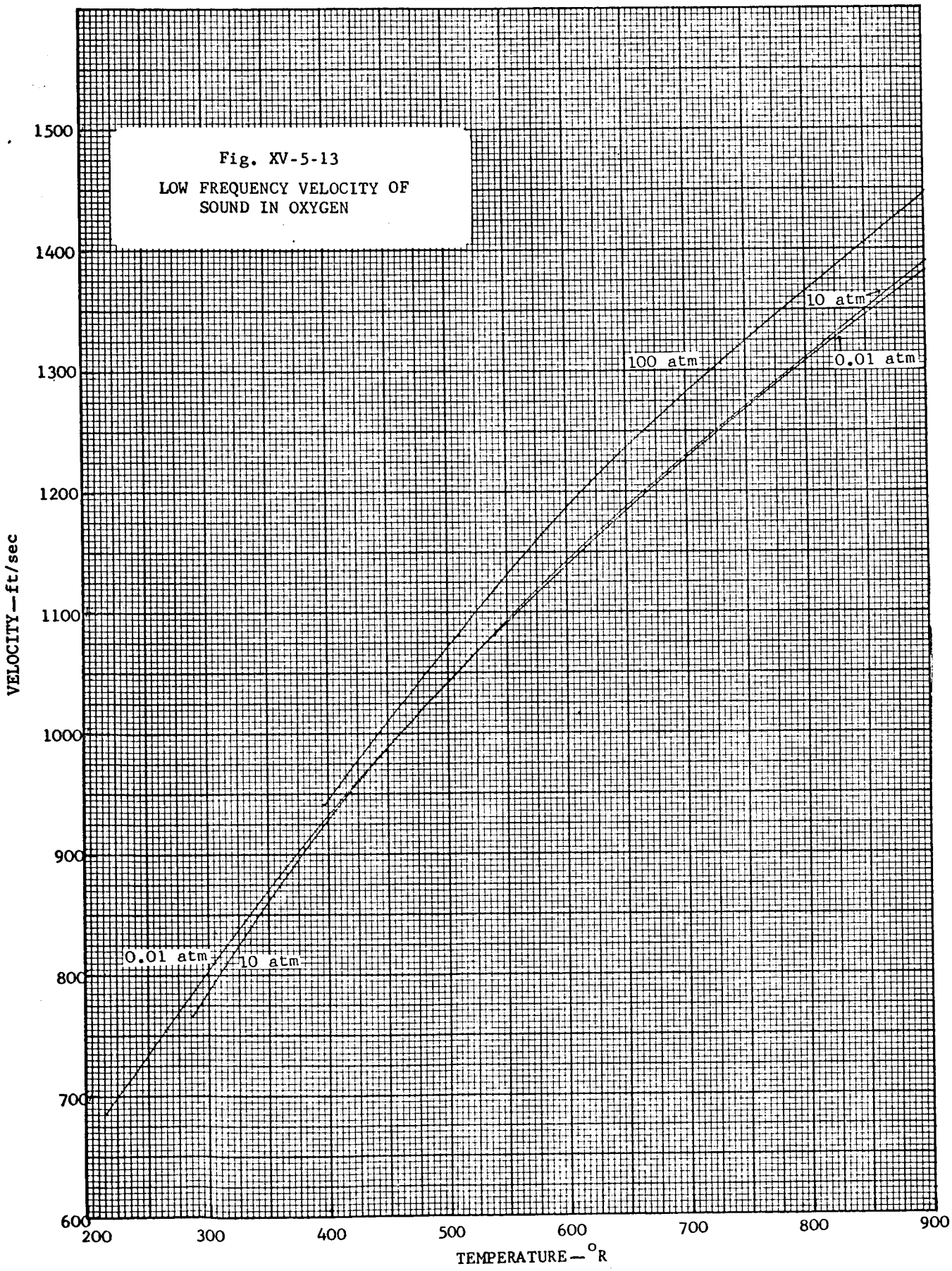

Fig. XV-5-13

LOW FREQUENCY VELOCITY OF SOUND IN OXYGEN

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Table XV-6-1

PHYSICAL CONSTANTS

OF

CARBON DIOXIDE

		REF.
Molecular Weight	44.01	3
Sublimation Point @ 1 atm	-109.3°F	3
Freezing Point @ 1 atm	-69.9°F	3
Specific Volume @ 70°F, 1 atm	8.76 cu ft/lb	3
Vapor Pressure @ 70°F	853.4 psia	3
Specific Gravity, (Air = 1)	1.5289	3
Density		
Liquid		
Gas @ 70°F, 1 atm	0.1146 lb/cu ft	3
Critical Temperature	87.8°F	3
Critical Pressure	1071.6 psia	3
Critical Density	29.22 lb/cu ft	3
Latent Heat of Vaporization @ b.p.	10854 Btu/lb-mole	3
Latent Heat of Fusion @ m.p.	3420 Btu/lb-mole	3
Specific Heat of Gas		
c_p @ 60°F	0.1988 Btu/lb-°F	3
c_v @ 60°F	0.1525 Btu/lb-°F	3
Specific Heat Ratio, c_p/c_v	1.304	
Thermal Conductivity @ 32°F	0.0085 Btu/hr-ft-°F	3
Viscosity		
Liquid @ 0°F	9.41×10^{-5} lb/ft-sec	6
Gas @ 70°F, 1 atm	9.95×10^{-6} lb/ft-sec	3
Solubility in Water @ 32°F	1.87 by volume	8
Surface Tension @ 68°F	7.95×10^{-5} lb/ft	7

Table XV-6-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR CARBON DIOXIDE
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.86450	1.92645	1417.02	27.4007
$mole/cm^3$	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.847809	62.3613	1.20587
lb/ft^3	0.0298662	0.0308586	22.6983	0.438914
$lb/mole/ft^3$	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.03583	1.07025	787.233	115.2226
$mole/cm^3$	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0165923	0.0171437	12.6102	0.243841
$lb/mole/ft^3$	0.730228	0.754489	554.973	10.7314

Table XV-6-2

VAPOR PRESSURE OF SOLID CARBON DIOXIDE
(Ref. 1,2)

TEMPERATURE		VAPOR PRESSURE
°K	°R	atm
93	167.4	0.000000017
103	185.4	0.000000524
113	203.4	0.00000776
123	221.4	0.0000796
133	239.4	0.000567
140	252.0	0.00183
150	270.0	0.00834
160	288.0	0.03114
170	306.0	0.09863
180	324.0	0.27314
190	342.0	0.6770
200	360.0	1.5339
210	378.0	3.2341
216	388.8	4.9207

(See Figure XV-6-1

Table XV-6-3

VAPOR PRESSURE OF LIQUID CARBON DIOXIDE (Ref. 2)

TEMPERATURE		VAPOR PRESSURE
°K	°R	atm
216	388.8	4.988
220	396.0	5.922
230	414.0	8.822
240	432.0	12.664
250	450.0	17.622
260	468.0	23.872
270	486.0	31.609
280	504.0	41.047
290	522.0	52.454
300	540.0	66.222
304	547.2	72.534

(See Figure XV-6-2)

Table XV-6-4

DENSITY OF CARBON DIOXIDE (Ref. 5)

TEMPERATURE		SATURATED LIQUID	SATURATED VAPOR
°K	°R	lb/ft^3	lb/ft^3
216.54	389.67	73.53 (tr. pt.)	0.861
222.04	399.67	72.27	1.085
227.59	409.67	70.96	1.335
233.15	419.67	69.61	1.636
238.71	429.67	68.21	1.985
244.26	439.67	66.76	2.395
249.82	449.67	65.25	2.880
255.37	459.67	63.65	3.450
260.93	469.67	61.96	4.115
266.48	479.67	60.13	4.890
272.04	489.67	58.16	5.800
277.59	499.67	55.98	6.935
283.15	509.67	53.56	8.303
288.71	519.67	50.80	10.07
294.26	529.67	47.35	12.44
299.82	539.67	42.36	16.44
304.15	547.47	28.96 (cryst.)	28.96 (c.p.)

Table XV-6-5

DENSITY OF CARBON DIOXIDE
(Ref. 5,9)

DENSITY-lb/ft^3							
PRESSURE psia / TEMP. °R	200	400	600	1000	2000	4000	6000
420	69.7	70.0	70.4	70.8	-	-	-
460	2.0	63.6	64.1	64.9	66.9	69.5	71.7
500	1.80	4.27	55.6	57.4	60.9	65.0	68.0
540	1.62	3.66	6.14	43.0	53.0	59.7	63.4
580	1.50	3.23	5.31	11.0	41.8	53.9	58.9
620	1.38	2.91	4.72	8.88	28.3	47.7	54.3
660	1.29	2.71	4.25	7.67	20.1	41.4	49.7
700	1.22	2.50	3.86	6.85	16.5	36.0	45.3
740	1.12	2.36	3.59	6.27	14.0	31.4	41.3
780	1.05	2.18	3.35	5.78	12.5	27.9	37.9

(See Figure XV-6-3)

Table XV-6-6

SURFACE TENSION OF LIQUID CARBON DIOXIDE (Ref. 4)

TEMPERATURE		SURFACE TENSION
^{o}K	^{o}R	lb/ft
223	401	0.0319
228	410	0.291
233	419	0.0263
238	428	0.0239
243	437	0.0218
248	446	0.0194
253	455	0.0173
258	464	0.0151
263	473	0.0131
268	482	0.0119
273	491	0.0093
278	500	0.0075
283	509	0.0058
288	518	0.0042
293	527	0.0029
298	536	0.0013
303	545	0.0002
308	555	0.0000 (Crit. Point)

(See Figure XV-6-4)

Table XV-6-7

HEAT OF VAPORIZATION OF CARBON DIOXIDE (Ref. 5)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
^{o}K	^{o}R	Btu/lb	^{o}K	^{o}R	Btu/lb
216.54	389.77	149.6	272.04	489.67	102.4
222.04	399.67	145.8	277.59	499.67	95.04
227.59	409.67	141.9	283.15	509.67	86.56
233.15	419.67	137.8	288.71	519.67	76.45
238.71	429.67	133.7	294.26	529.67	63.90
244.26	439.67	129.5	299.82	539.67	45.30
249.82	449.67	124.9	304.15	547.47	0.00
255.37	459.67	120.0			
260.93	469.67	114.9			
266.48	479.67	109.0			

(See Figure XV-6-5)

Table XV-6-8

HEAT CAPACITIES OF GASEOUS CARBON DIOXIDE (Ref. 2)

TEMPERATURE		HEAT CAPACITY, C_p--Btu/lb-^oR		
^oK	^oR	1 atm	10 atm	100 atm
220	396	0.1870		
230	414	0.1884		
240	432	0.1903	0.331019	
250	450	0.1923	0.2603	
260	468	0.1945	0.2314	
270	486	0.1968	0.21845	
280	504	0.1990	0.21856	
290	522	0.2013	0.2189	
300	540	0.2036	0.2194	
310	558	0.2059	0.2199	
320	576	0.2081	0.2206	0.9331
330	594	0.2104	0.2213	0.5166
340	612	0.2126	0.2225	0.4138
350	630	0.21467	0.2238	0.3912
360	648	0.2168	0.2251	0.3722
370	666	0.2189	0.2265	0.3528
380	684	0.2209	0.2279	0.3366
390	702	0.2230	0.2293	0.3240
400	720	0.2249	0.2303	0.31401
410	738	0.2268	0.2323	0.3058
420	756	0.2287	0.2337	0.29745
430	774	0.2305	0.2352	0.2933
440	792	0.2323	0.2367	0.2885
450	810	0.2341	0.2382	0.2832
460	828	0.2359	0.2397	0.2765
470	846	0.2376	0.2411	0.2725
480	864	0.2392	0.2426	0.2695
490	882	0.2409	0.2441	0.2693
500	900	0.2425	0.2455	0.2714

(See Figure XV-6-6)

Table XV-6-9

VISCOSITY OF CARBON DIOXIDE AT ATMOSPHERIC PRESSURE (Ref. 2)

TEMPERATURE		VISCOSITY
^{o}K	^{o}R	lb/sec-ft (10^{-6})
190	342	6.45
200	360	6.79
210	378	7.13
220	396	7.47
230	414	7.80
240	432	8.13
250	450	8.46
300	540	10.10
350	630	11.56
400	720	12.98
450	810	14.34
500	900	15.62
550	990	16.85
600	1080	18.03
650	1170	19.15
700	1260	20.25
750	1350	21.30
800	1440	22.33
850	1530	23.31
900	1620	24.27
950	1710	25.23
1000	1800	26.15
1100	1980	27.89
1200	2160	29.63
1300	2340	31.25
1400	2520	32.87
1500	2700	34.41
1600	2800	35.93
1700	3060	37.40

(See Figure XV-6-9).

Table XV-6-10

THERMAL CONDUCTIVITY OF GASEOUS CARBON DIOXIDE (Ref. 2)

TEMPERATURE		THERMAL CONDUCTIVITY	TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R	°K	°R	Btu/hr-ft-°R
180	324	0.00477	350	630	0.01182
190	342	0.00513	360	648	0.01231
200	360	0.00554	370	666	0.01276
210	378	0.00588	380	684	0.01325
220	396	0.00625	390	702	0.01374
230	414	0.00665	400	720	0.01422
240	432	0.00704	410	730	0.01473
250	450	0.00745	420	756	0.01523
260	468	0.00786	430	774	0.01571
270	486	0.00827	440	792	0.01623
280	504	0.00870	450	810	0.01673
290	522	0.00914	460	828	0.01726
300	540	0.00958	470	846	0.01777
310	558	0.01001	480	864	0.01830
320	576	0.01044	490	882	0.01883
330	594	0.01090	500	900	0.01937
340	612	0.01137			

(See Figure XV-6-10)

Table XV-6-11

TOTAL ENTHALPY OF CARBON DIOXIDE (Ref. 2)

TEMPERATURE		TOTAL ENTHALPY—Btu/lb				
°K	°R	0.01 atm	1.0 atm	10 atm	70 atm	100 atm
200	360	58.136				
220	396	64.557	63.70			
240	432	71.168	70.49	62.52		
260	468	77.975	77.41	72.15		
280	504	84.971	84.49	80.09		
300	540	92.155	91.74	87.97		
320	576	99.514	99.15	95.89	67.7	46.4
340	612	107.04	106.7	103.9	81.4	67.2
360	648	114.74	114.5	112.0	92.7	81.2
380	684	122.59	122.3	120.1	103.4	94.1
400	720	130.59	130.4	128.4	113.8	105.9
420	756	138.74	138.5	137.3	123.8	116.9
440	792	147.02	146.8	145.7	133.6	127.4
460	828	155.43	155.3	154.3	143.2	137.6
480	864	163.97	163.8	162.9	152.8	147.4
500	900	172.63	172.5	171.7	162.3	157.1

(See Figure XV-6-11)

Table XV-6-12

LOW FREQUENCY VELOCITY OF SOUND IN CARBON DIOXIDE (Ref. 2)

TEMPERATURE		VELOCITY--Ft/sec				
°K	°R	0.01 atm	1.0 atm	10 atm	70 atm	100 atm
200	360	736.6				
220	396	768.7	762.			
240	432	799.0	794.	728.		
260	468	828.0	824.	782.		
280	504	855.76	852.5	825.		
300	540	882.58	880.3	856.7		
320	576	908.46	906.4	887.0	719.	554.
340	612	933.51	931.7	916.6	827.	782.
360	648	957.88	956.2	944.4	886.2	828.
380	684	981.65	980.6	970.5	925.0	891.3
400	720	1004.8	1004.	995.8	952.8	936.8
420	756	1027.4	1027.	1020.	987.4	982.3
440	792	1049.5	1049.	1044.	1019.	1022.
460	828	1071.1	1071.	1067.	1050.	1054.
480	864	1092.4	1092.	1089.	1078,	1084.
500	900	1113.1	1113.	1110.	1106.	1115.

(See Figure XV-6-12)

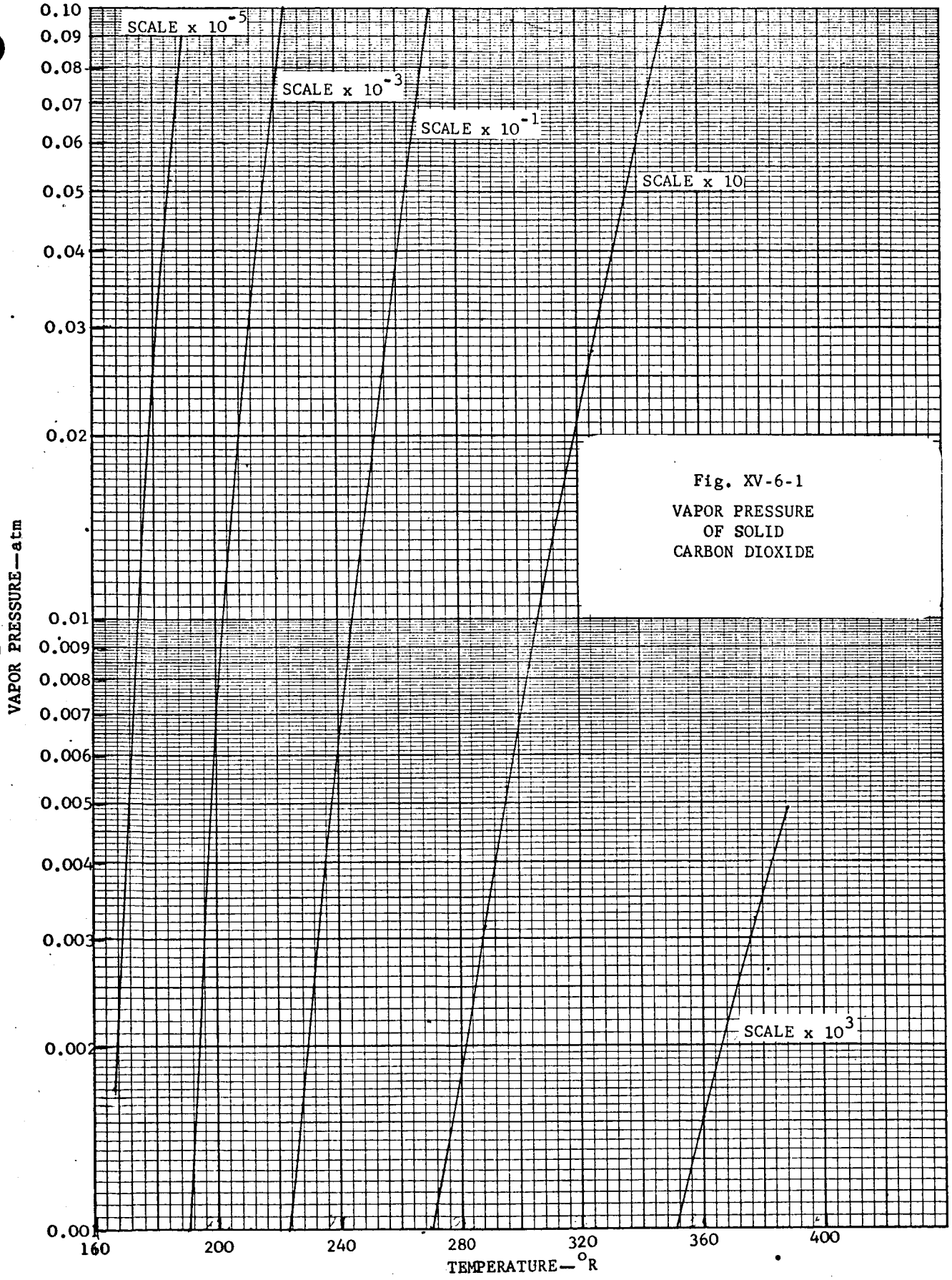

Fig. XV-6-1

VAPOR PRESSURE OF SOLID CARBON DIOXIDE

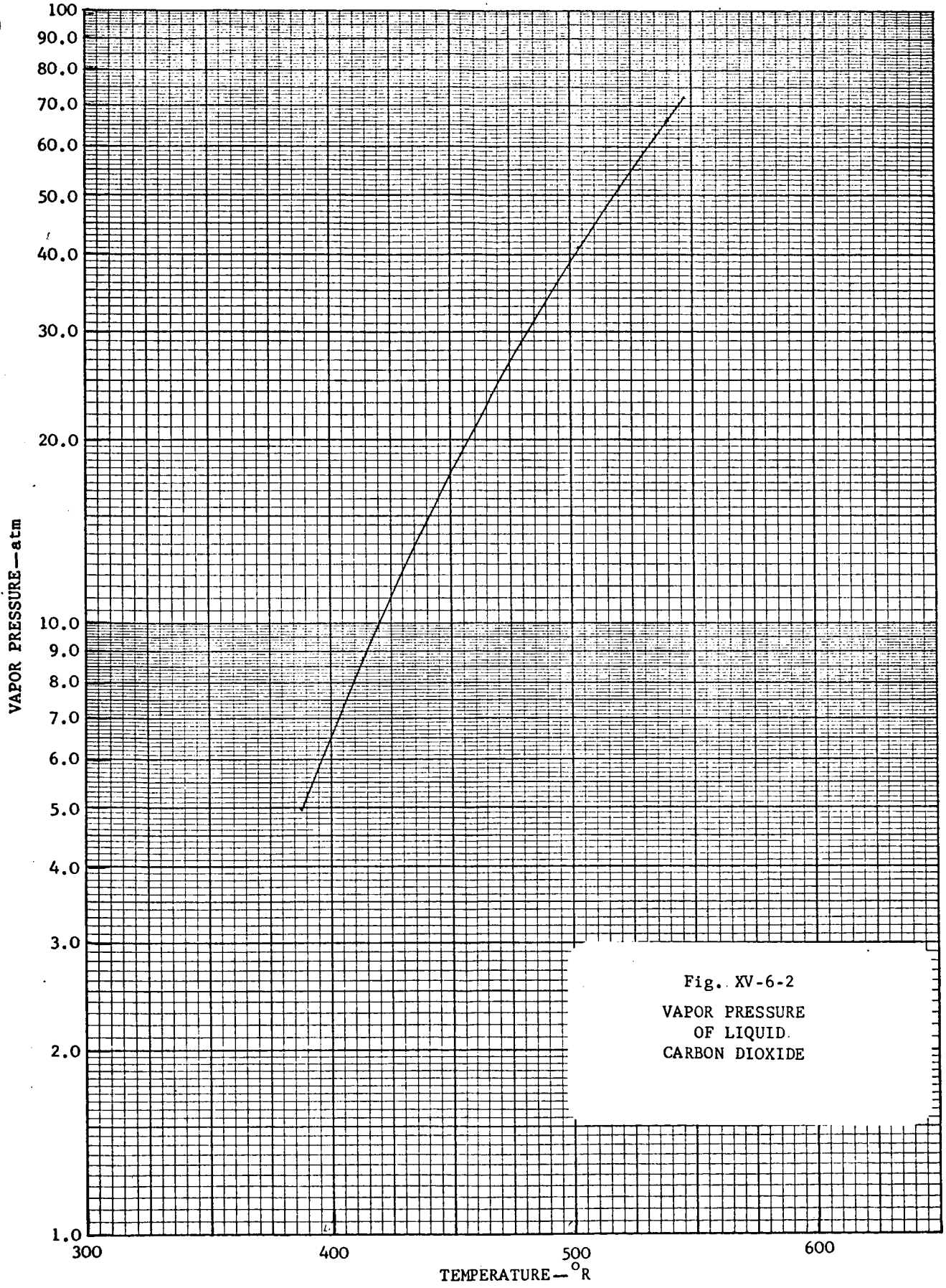

Fig. XV-6-2

VAPOR PRESSURE
OF LIQUID
CARBON DIOXIDE

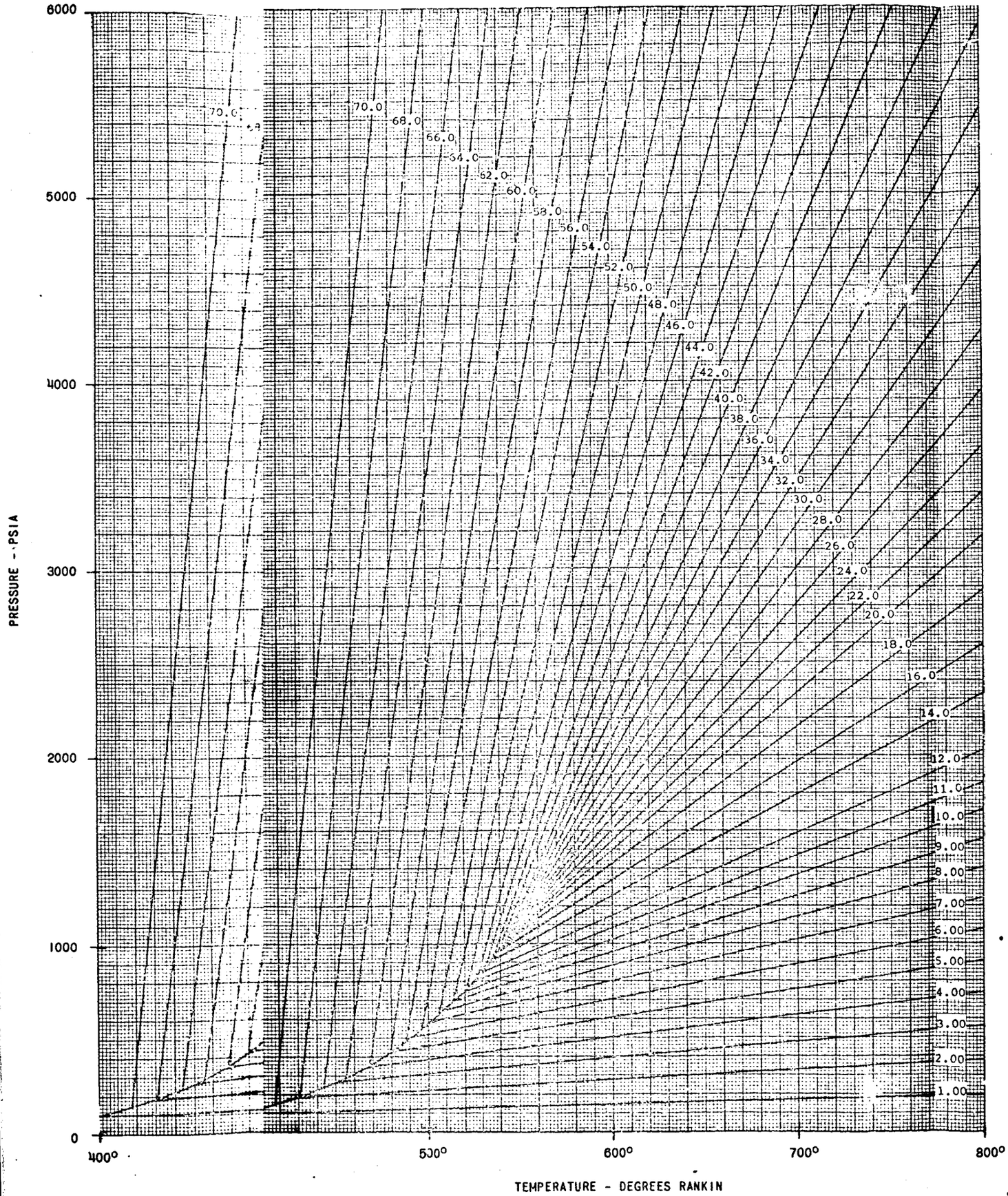

FIG. XV-6-3-2
CARBON DIOXIDE (CO_2)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

XV-6-3-1 XV-6-3-1

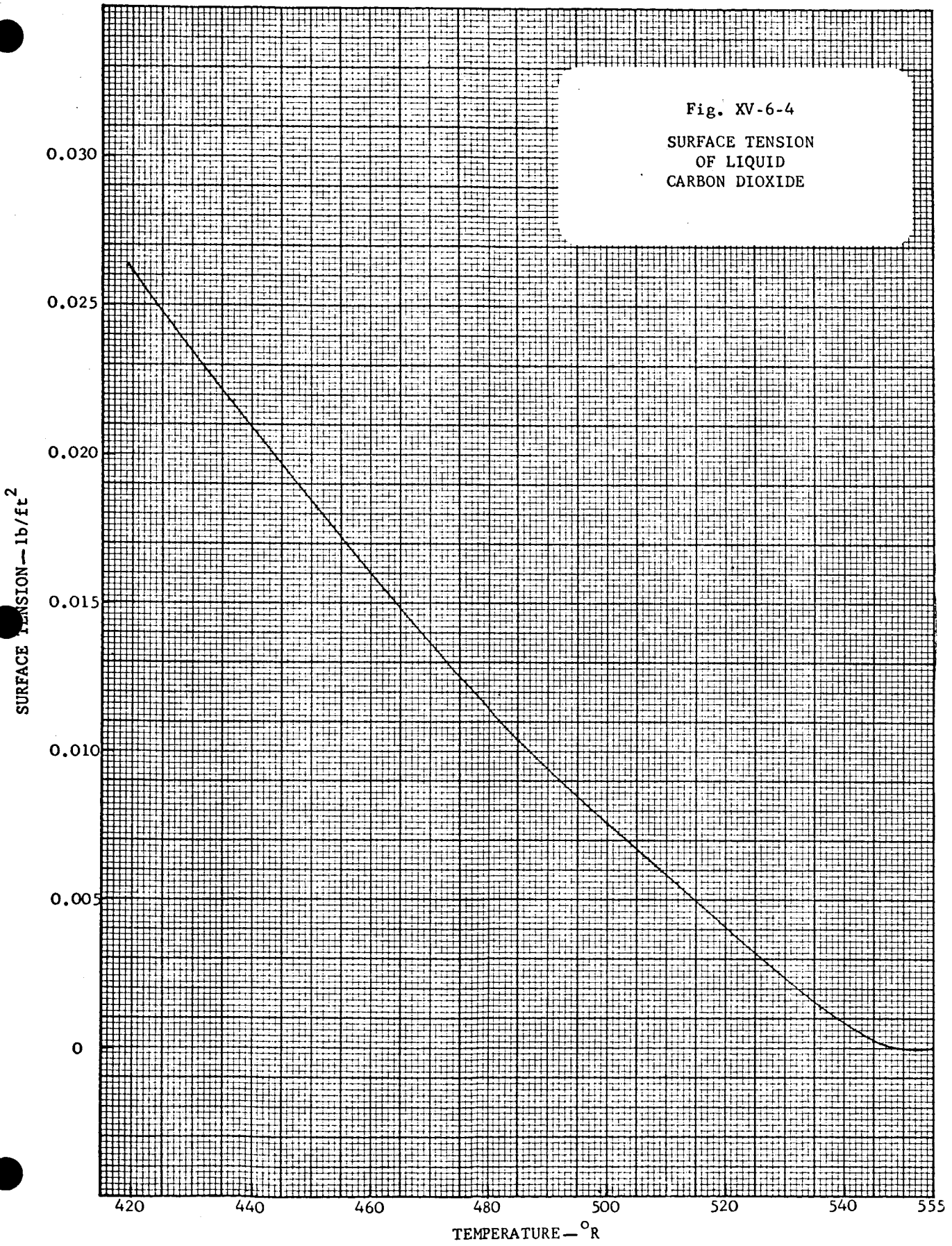

Fig. XV-6-4

SURFACE TENSION
OF LIQUID
CARBON DIOXIDE

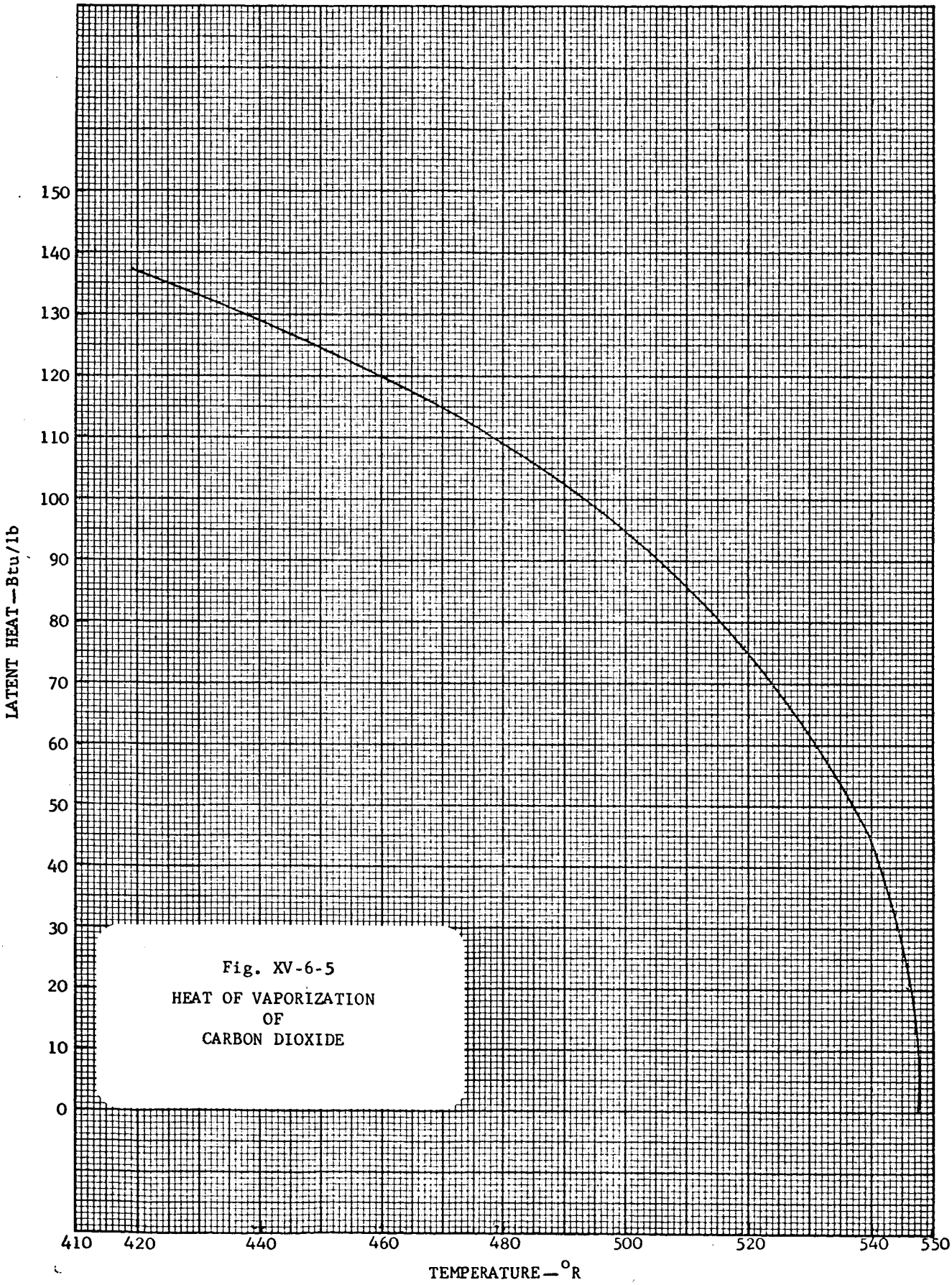

Fig. XV-6-5
HEAT OF VAPORIZATION
OF
CARBON DIOXIDE

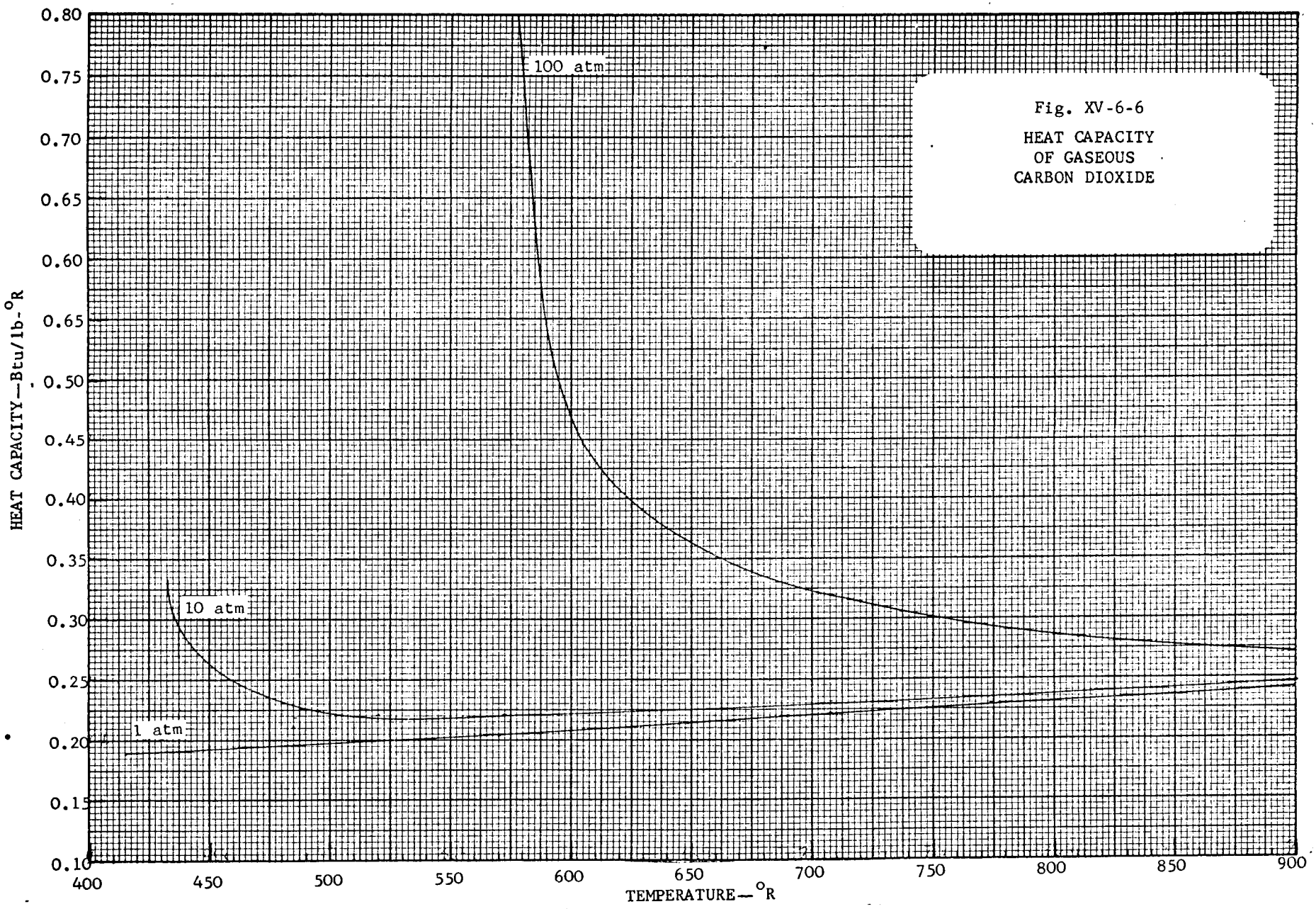

Fig. XV-6-6

HEAT CAPACITY
OF GASEOUS
CARBON DIOXIDE

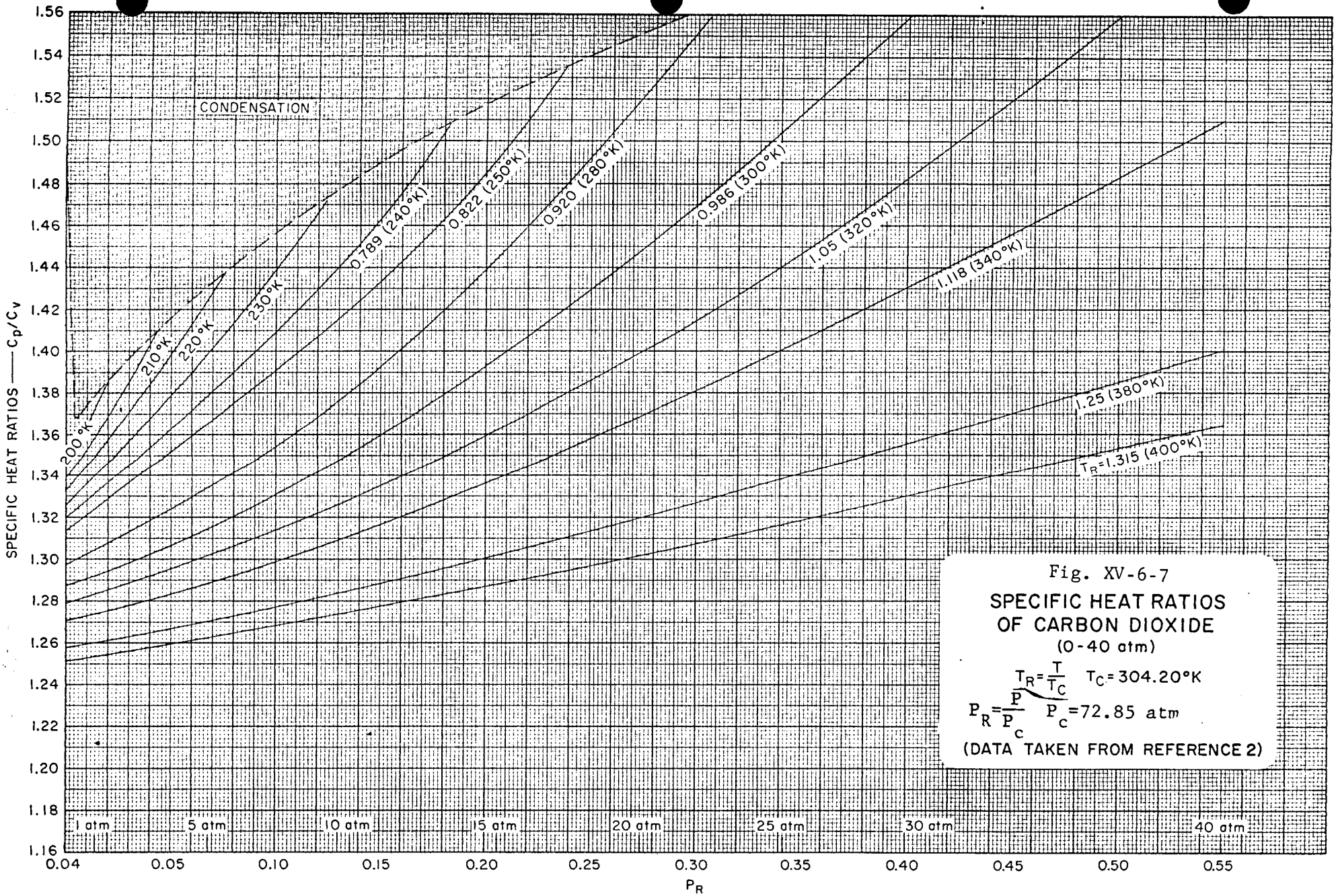

Fig. XV-6-7

SPECIFIC HEAT RATIOS OF CARBON DIOXIDE

(0-40 atm)

$T_R = \frac{T}{T_C}$ $T_C = 304.20°K$

$P_R = \frac{P}{P_c}$ $P_c = 72.85$ atm

(DATA TAKEN FROM REFERENCE 2)

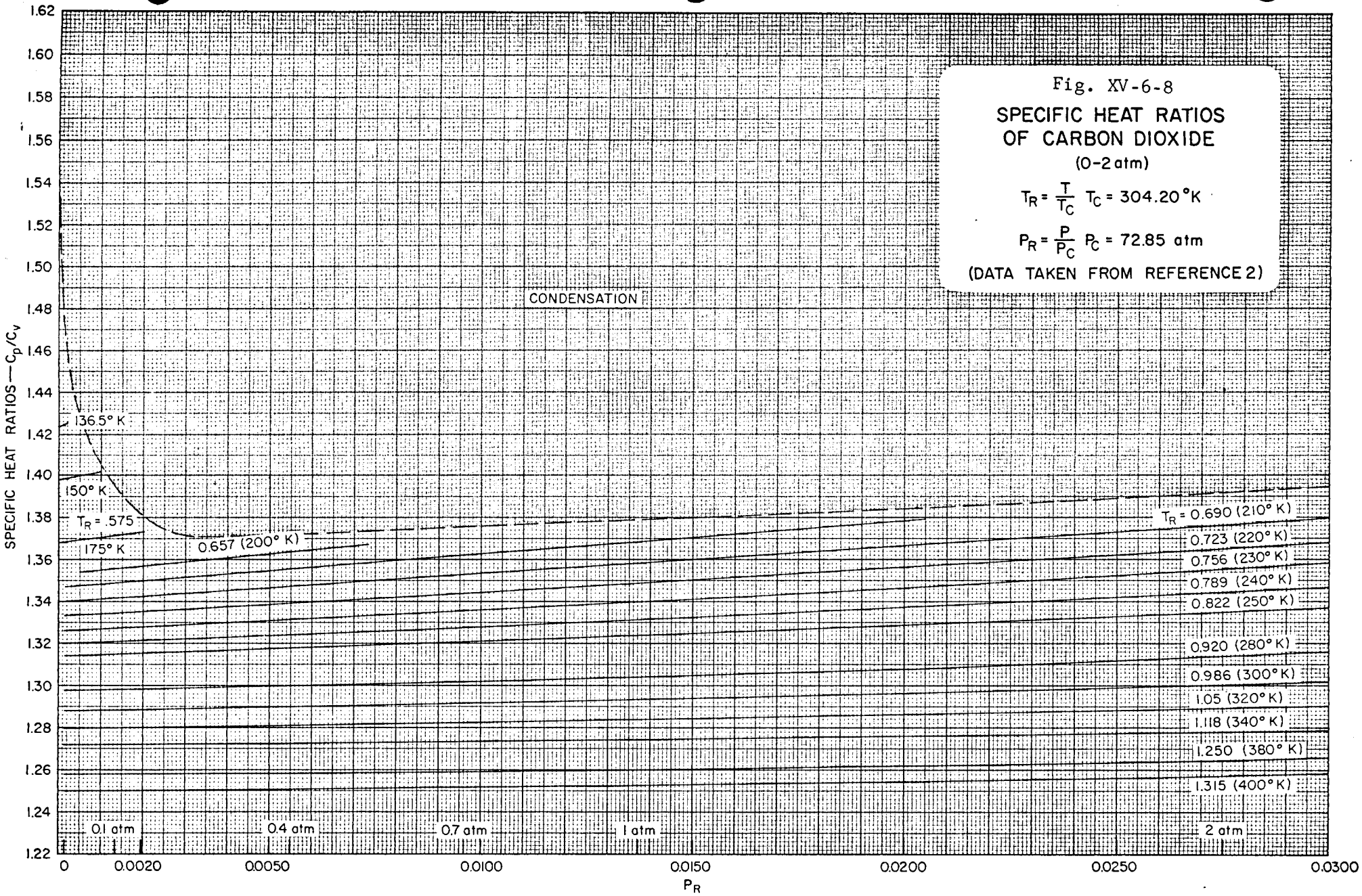
Fig. XV-6-8
SPECIFIC HEAT RATIOS OF CARBON DIOXIDE
(0-2 atm)
$T_R = \frac{T}{T_C}$ T_C = 304.20 °K
$P_R = \frac{P}{P_C}$ P_C = 72.85 atm
(DATA TAKEN FROM REFERENCE 2)
CONDENSATION
136.5° K
150° K
T_R = .575
175° K
0.657 (200° K)
T_R = 0.690 (210° K)
0.723 (220° K)
0.756 (230° K)
0.789 (240° K)
0.822 (250° K)
0.920 (280° K)
0.986 (300° K)
1.05 (320° K)
1.118 (340° K)
1.250 (380° K)
1.315 (400° K)
0.1 atm
0.4 atm
0.7 atm
1 atm
2 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.62
1.60
1.58
1.56
1.54
1.52
1.50
1.48
1.46
1.44
1.42
1.40
1.38
1.36
1.34
1.32
1.30
1.28
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0.0200
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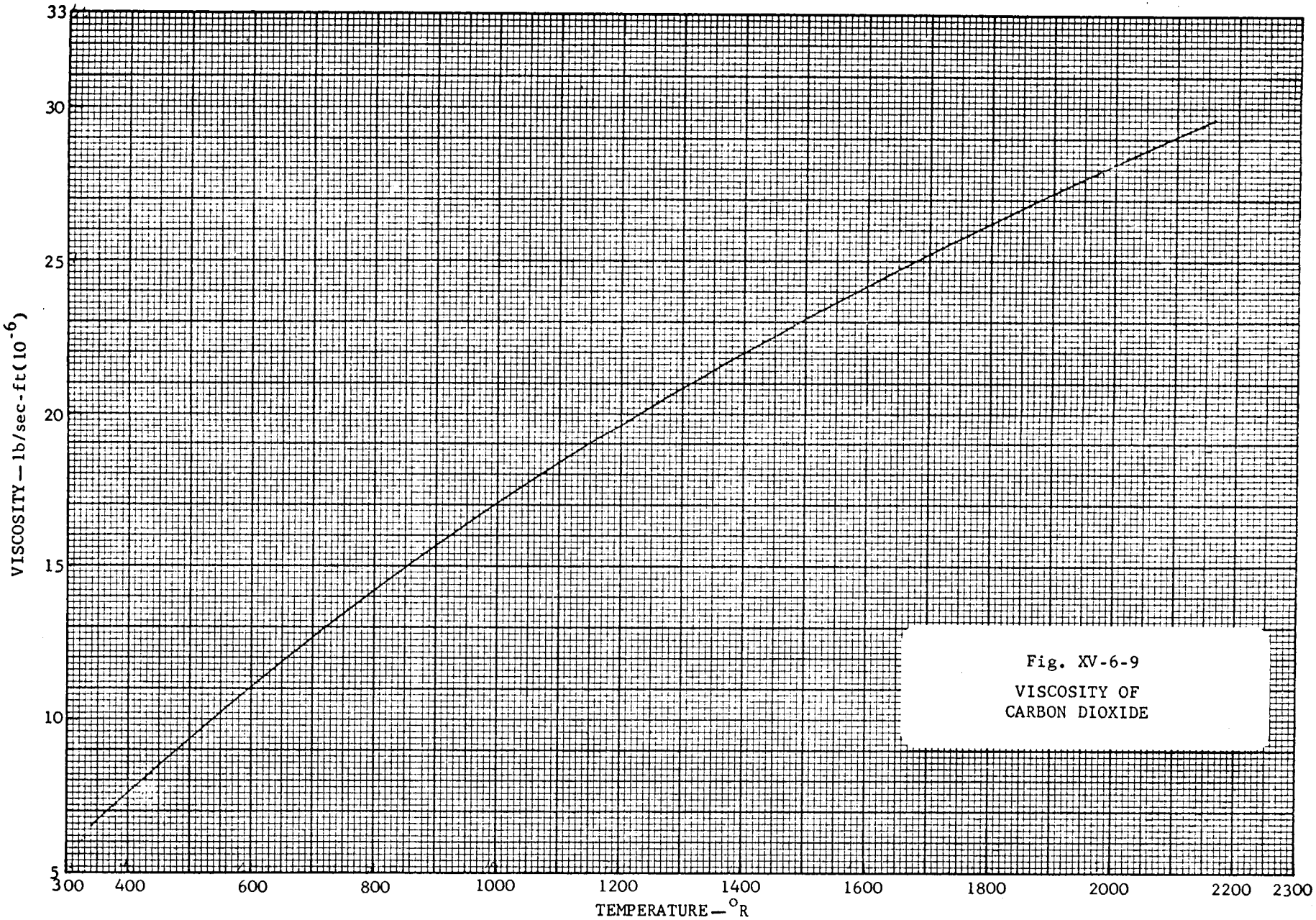

Fig. XV-6-9

VISCOSITY OF
CARBON DIOXIDE

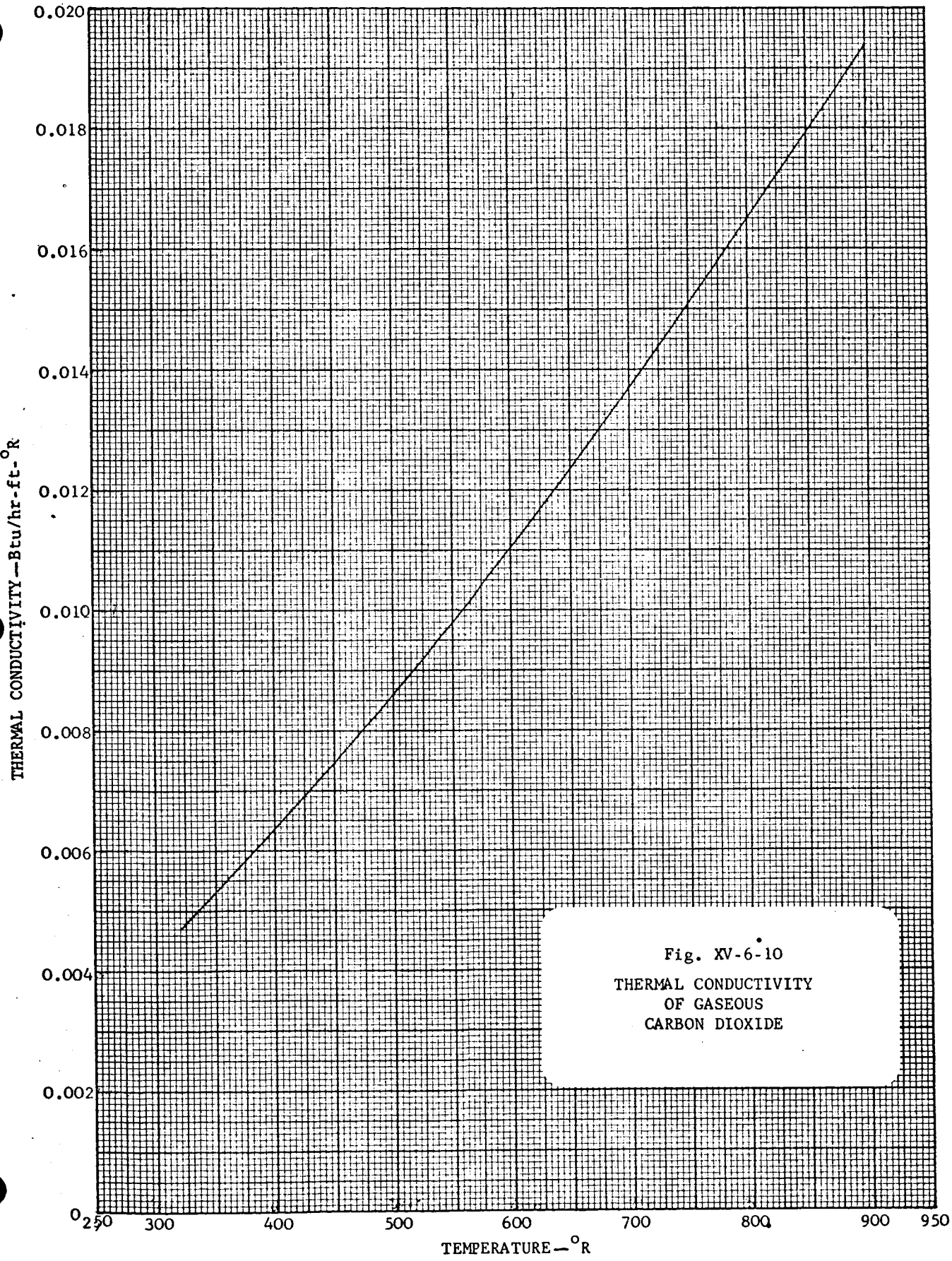

Fig. XV-6-10

THERMAL CONDUCTIVITY
OF GASEOUS
CARBON DIOXIDE

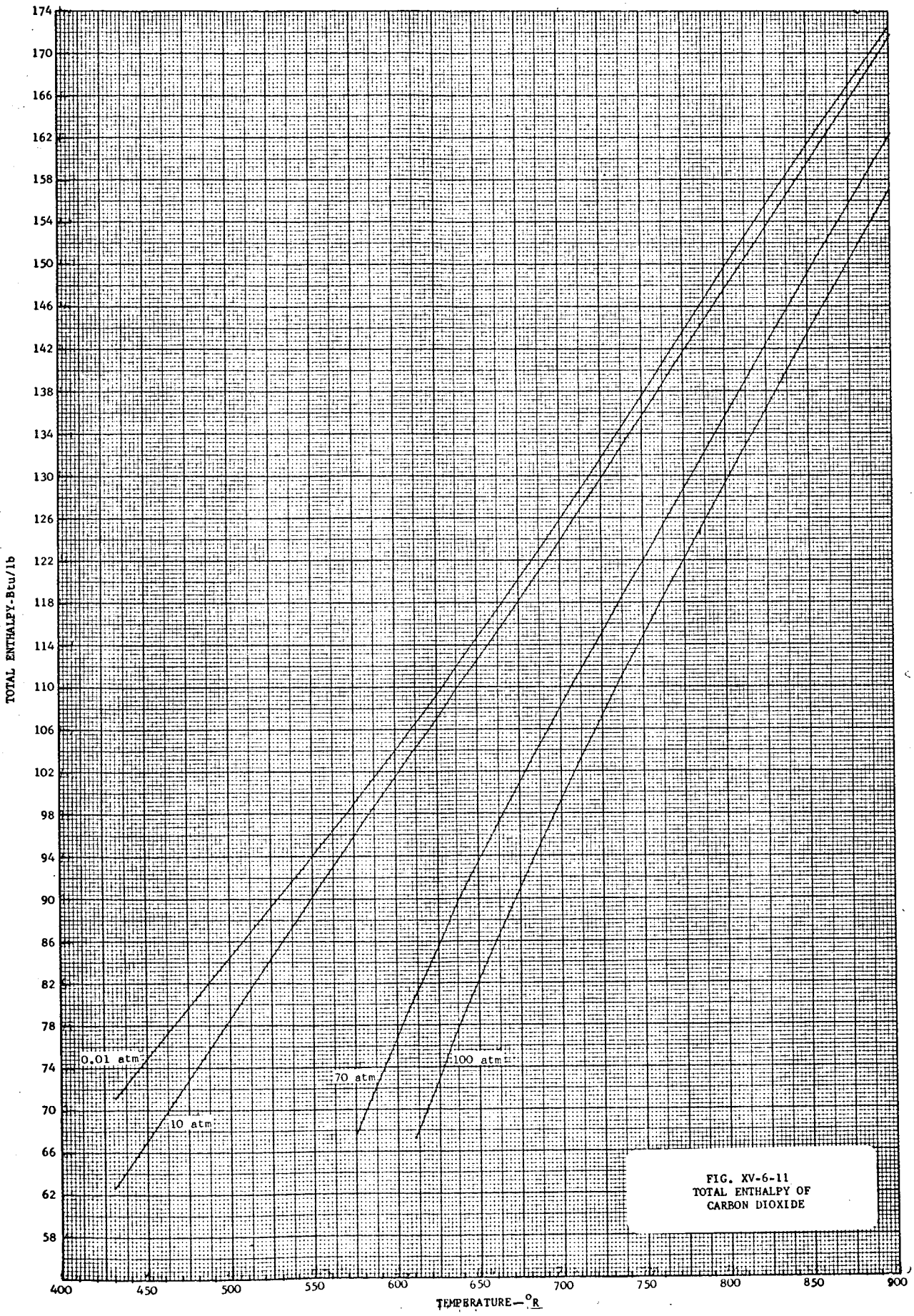

FIG. XV-6-11
TOTAL ENTHALPY OF
CARBON DIOXIDE

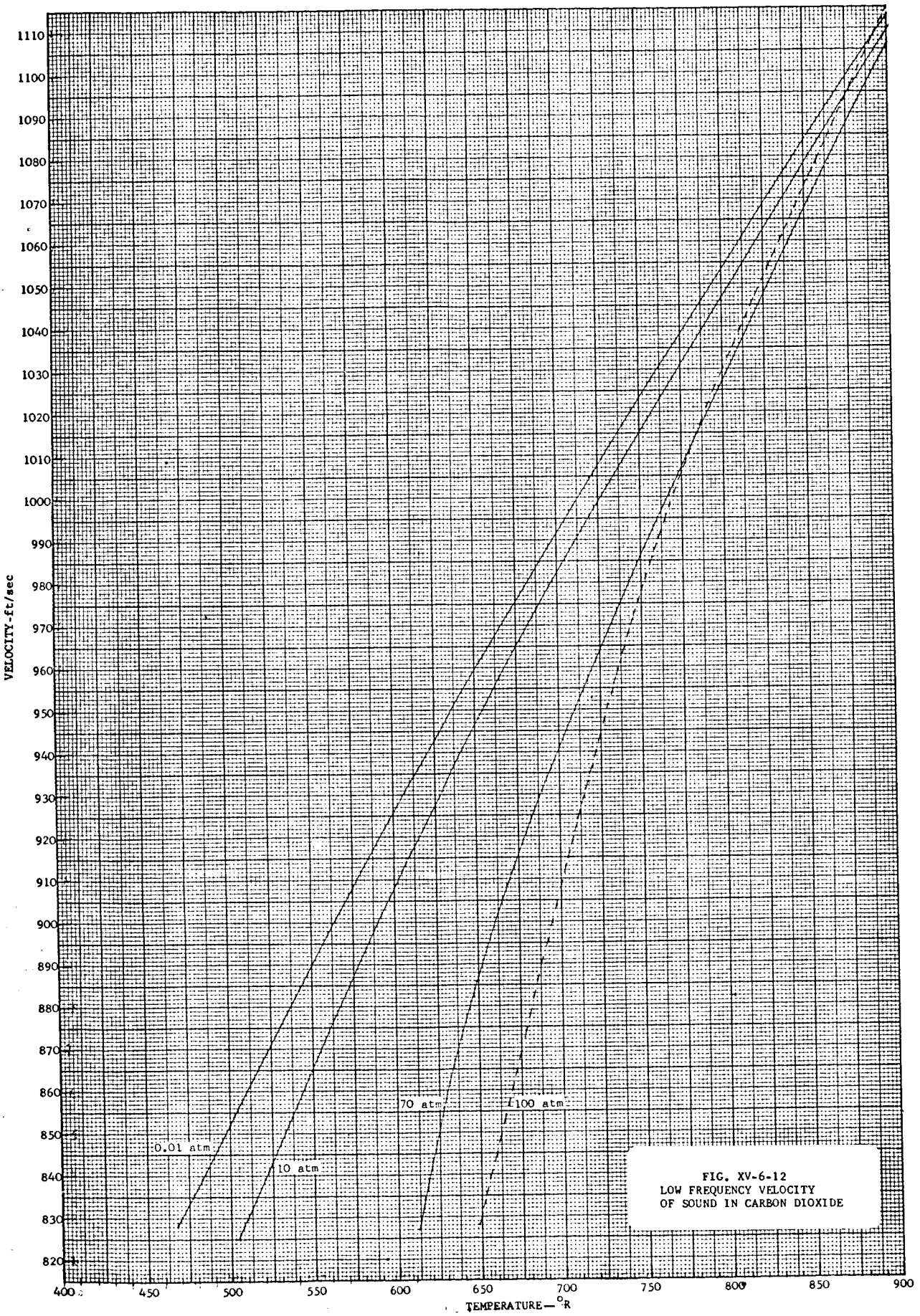

FIG. XV-6-12
LOW FREQUENCY VELOCITY
OF SOUND IN CARBON DIOXIDE

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Table XV-7-1

GENERAL PROPERTIES OF PERCHLORYL FLUORIDE

PROPERTY	TEMPERATURE				PRESSURE			REF
	°C	°K	°F	°R	psia	atm	mm of Hg	
Melting Point		127.						4
Boiling Point	- 46.67	226.48	- 52.87	406.80				5
Triple Point		125.41						5
Critical Temp.	95.2	368.3	203.3	662.9				3
Critical Press.					778.9	53.0		3
Mol. Wt. 102.457								
Heat of Vaporization 45.08 cal/g or 81.14 Btu/lb @ 226.48°K								5
Heat of Fusion 8.943 cal/g or 16.10 Btu/lb								5
Surface Tension 24.05 dynes/cm at 198°K								4

Table XV-7-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR PERCHLORYLFLUORIDE

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.800889	0.827500	608.676	11.7699
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0128289	0.0132551	9.74996	0.188534
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.444938	0.459722	338.153	6.53884
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00712717	0.00736396	5.41664	0.104562
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-7-2

VAPOR PRESSURE OF LIQUID PERCHLORYL FLUORIDE (Ref. 3)

TEMPERATURE		VAPOR PRESSURE		TEMPERATURE		VAPOR PRESSURE	
°K	°R	mm Hg	psia	°K	°R	atm	psia
152.81	273.78	3.08	0.0596	227.09	408.76	1.033	15.18
157.67	283.81	5.53	0.1069	232.04	417.67	1.290	18.96
162.58	292.64	9.31	0.1801	237.14	426.85	1.606	23.60
167.50	301.50	14.97	0.2895	242.09	435.76	1.969	28.94
172.33	310.19	23.19	0.4484	251.99	453.58	2.891	42.49
177.40	319.32	35.73	0.6909	262.07	471.73	4.048	59.49
182.33	328.19	53.05	1.026	272.04	489.67	5.748	84.47
187.31	337.16	77.13	1.491	282.10	507.78	7.789	114.47
192.25	346.05	109.48	2.226	292.13	525.83	10.170	149.46
197.19	354.94	151.77	2.935	292.24	526.03	10.177	149.56
202.11	363.80	207.50	4.0182	302.17	543.91	13.361	196.35
207.19	372.94	279.66	5.408	312.21	561.98	17.034	250.33
212.20	381.96	370.73	7.169	322.33	580.19	21.388	314.32
217.73	391.91	481.49	9.311	332.41	598.34	26.490	389.30
222.13	399.83	619.33	11.976	342.50	616.50	32.782	481.76
				352.66	634.79	39.959	587.24
				362.92	653.26	48.259	709.21

(See Figure XV-7-1)

Table XV-7-3

DENSITY OF LIQUID PERCHLORYL FLUORIDE (Ref. 1,3).

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft^3	°K	°R	lb/ft^3
131.31	236.36	124.2	273.15	491.67	95.52
144.46	260.03	121.7	299.55	539.19	88.65
149.58	269.24	120.8	314.45	566.01	84.28
154.79	278.62	119.9	321.35	578.43	81.78
159.84	287.71	118.9	327.15	588.87	79.29
164.66	296.39	118.1	333.75	600.75	76.79
169.62	305.32	117.2	343.45	618.21	72.42
174.50	314.10	116.2	348.15	626.67	70.23
179.52	323.14	115.2	354.55	638.19	66.18
184.54	332.17	114.3	358.15	644.67	63.68
189.50	341.10	113.4	362.95	653.31	59.06
194.44	349.99	112.4	366.05	658.89	54.50
199.38	358.88	111.5			
204.34	367.81	110.5			
209.21	376.58	109.3			
214.21	385.58	108.2			
219.15	394.47	107.3			
224.11	403.40	106.2			
229.23	412.61	105.1			
234.22	421.60	104.1			

(See Figure XV-7-2)

Table XV-7-4

DENSITY OF SATURATED VAPOR
OF PERCHLORYL FLUORIDE
(Ref. 1)

TEMPERATURE		DENSITY
°K	°R	lb/ft^3
273.15	491.67	2.04
299.55	539.19	3.91
314.45	566.01	6.45
321.35	578.43	6.92
327.15	588.87	7.99
333.75	600.75	9.35
343.45	618.21	12.05
348.15	626.67	13.58
354.55	638.19	16.36
358.15	644.67	18.23
362.95	653.31	21.76
366.05	658.89	25.57

(See Figure XV-7-3)

Table XV-7-5

VISCOSITY OF LIQUID PERCHLORYL FLUORIDE (Ref. 6)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises	°K	°R	centipoises
190.15	342.27	0.630	270.15	486.27	0.240
200.15	360.27	0.549	280.15	504.27	0.217
210.15	378.27	0.482	290.15	522.27	0.197
220.15	396.27	0.425	300.15	540.27	0.178
230.15	414.27	0.377	310.15	558.27	0.163
240.15	432.27	0.335	320.15	576.27	0.150
250.15	450.27	0.299	330.15	594.27	0.138
260.15	468.27	0.273			

(See Figure XV-7-4)

Table XV-7-6

HEAT CAPACITY OF SATURATED LIQUID PERCHLORYL FLUORIDE (Ref. 4)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb-°R	°K	°R	Btu/lb-°R
226.09	406.96	0.2245	278.68	501.64	0.2537
227.58	409.64	0.2267	285.11	513.20	0.2547
233.84	420.91	0.2306	292.01	525.62	0.2602
238.72	429.70	0.2323	298.86	537.95	0.2653
240.25	432.45	0.2346	306.00	550.80	0.2696
243.86	438.95	0.2339	311.41	560.54	0.2769
249.42	448.96	0.2367	318.16	572.69	0.2835
253.74	456.73	0.2406	325.40	585.72	0.2925
255.12	459.22	0.2401	332.88	599.18	0.3023
260.19	468.34	0.2421	340.87	613.57	0.3287
260.76	469.37	0.2424	344.99	619.37	0.3491
261.23	470.21	0.2432	347.99	626.38	0.3614
265.09	477.16	0.2447	356.49	641.68	0.4391
272.31	490.16	0.2492	357.94	644.29	0.4597
277.33	499.19	0.2526	360.18	648.32	0.6106
278.69	501.64	0.2532			

(See Figure XV-7-5)

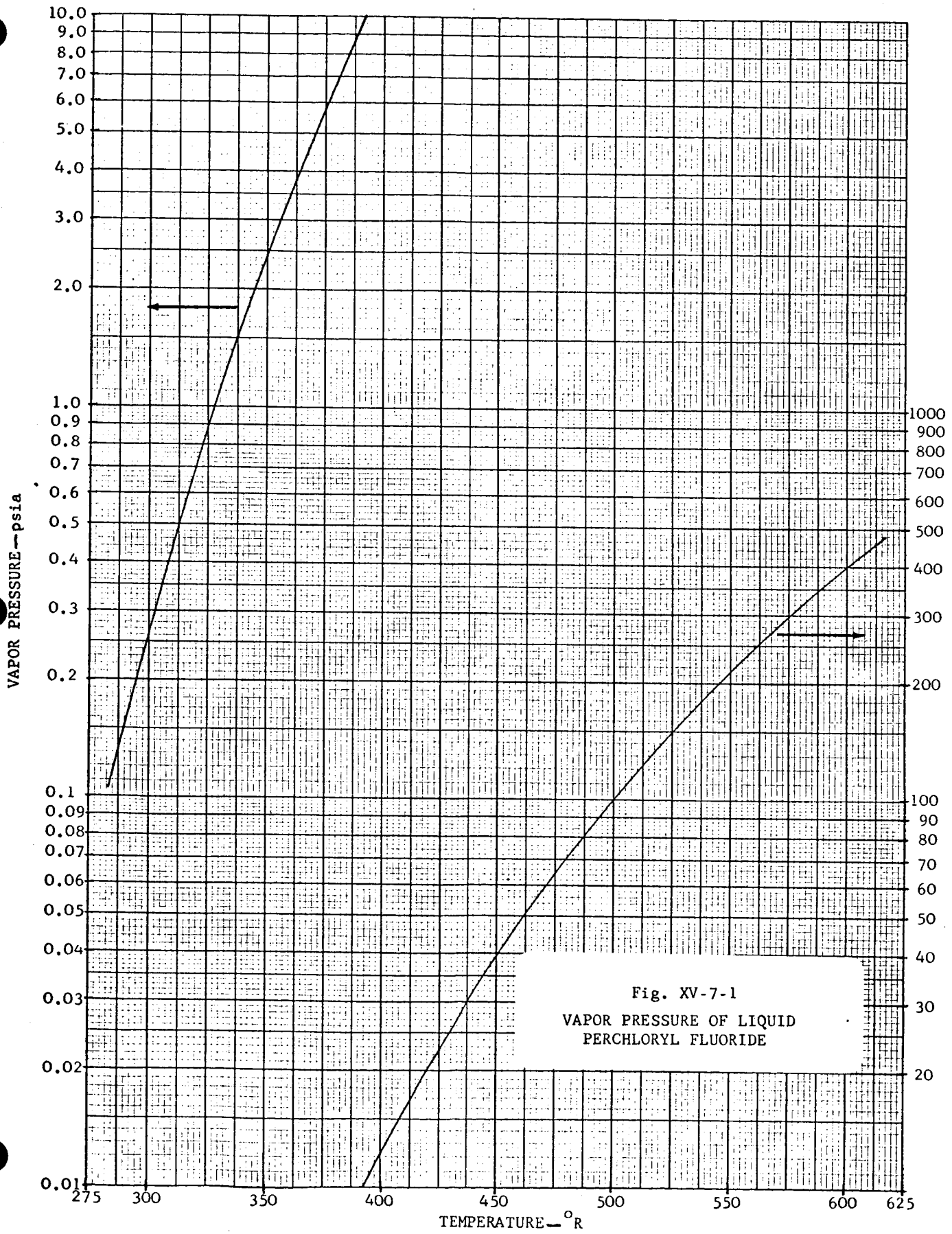

Fig. XV-7-1

VAPOR PRESSURE OF LIQUID PERCHLORYL FLUORIDE

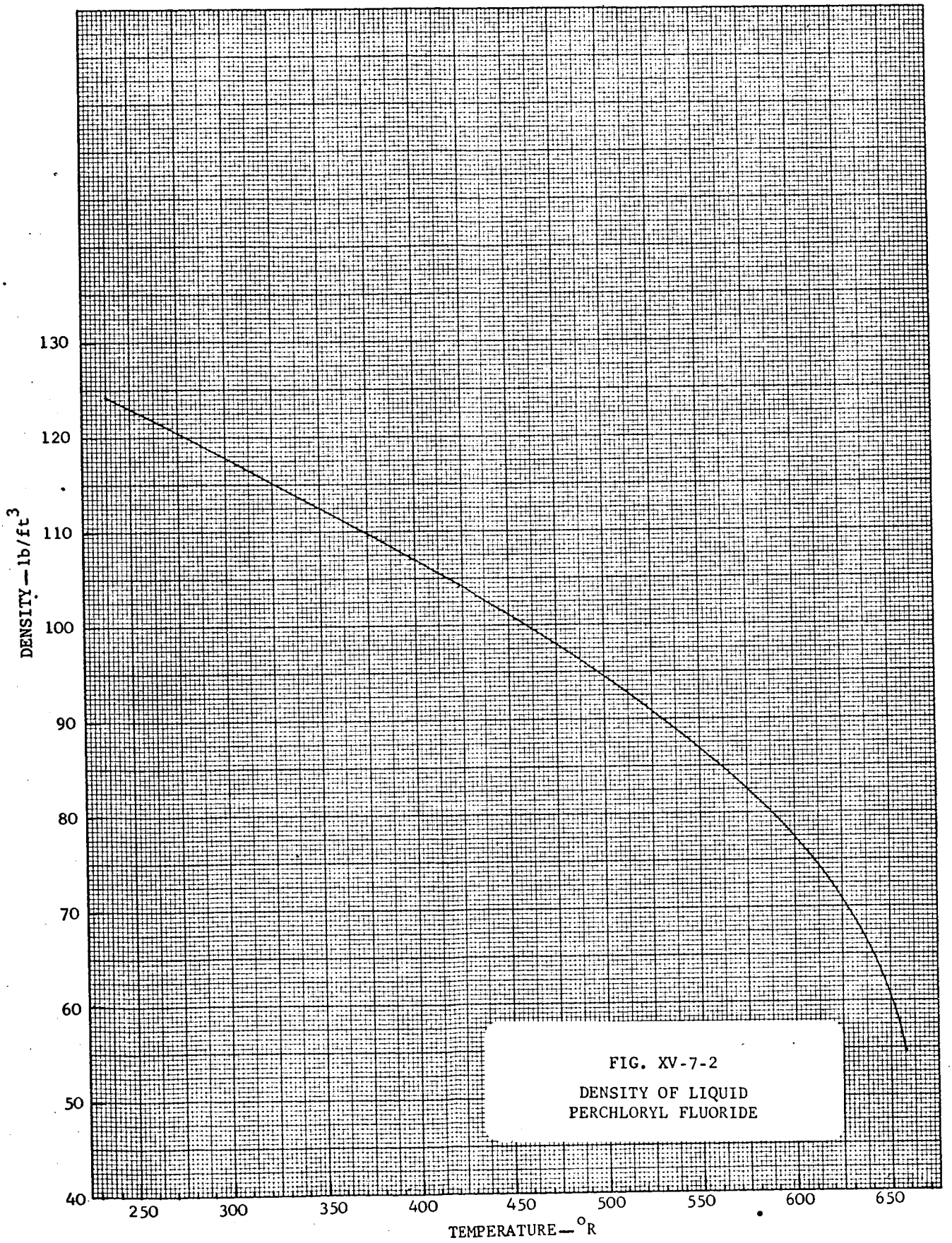

FIG. XV-7-2

DENSITY OF LIQUID
PERCHLORYL FLUORIDE

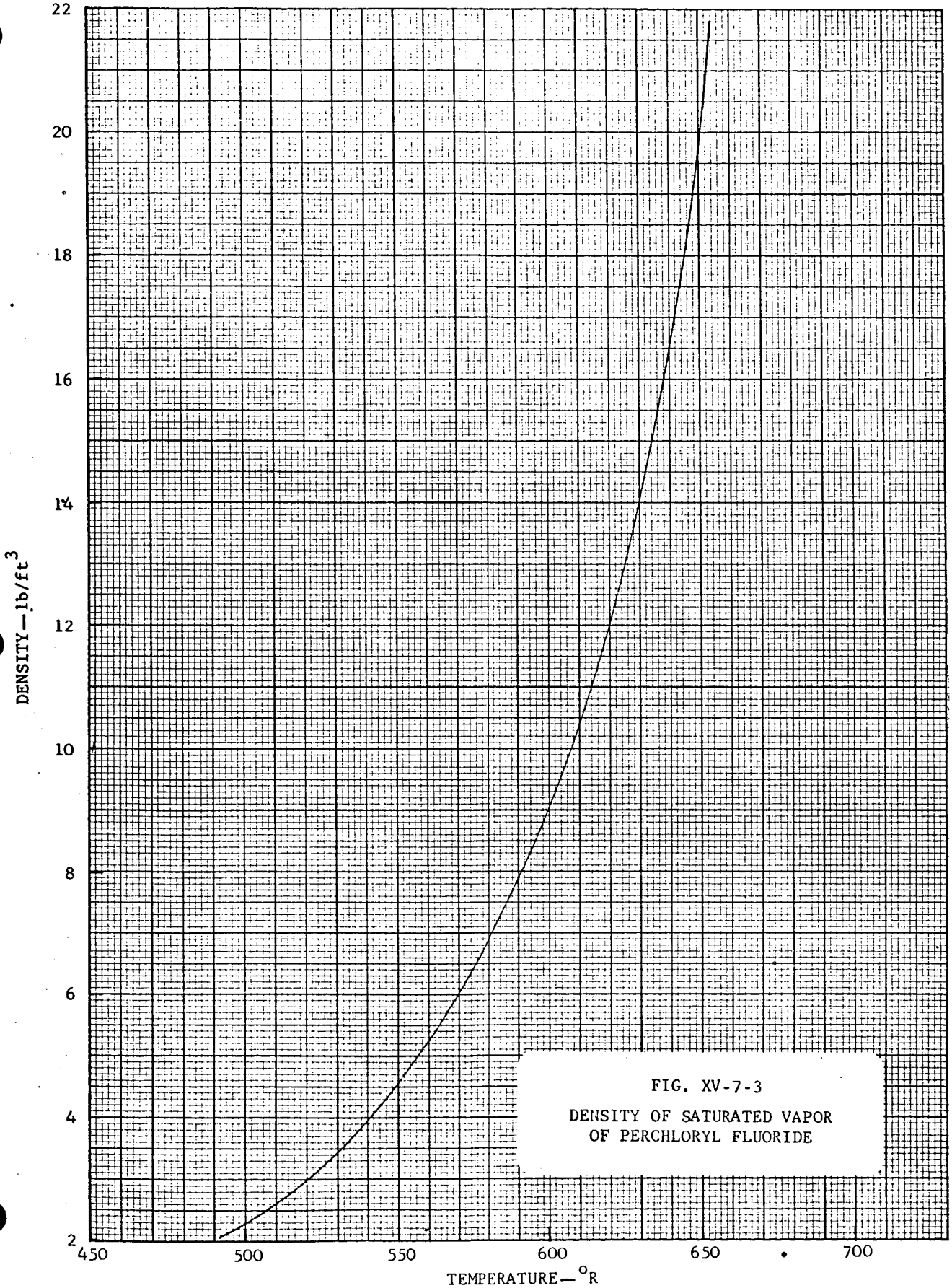

FIG. XV-7-3

DENSITY OF SATURATED VAPOR OF PERCHLORYL FLUORIDE

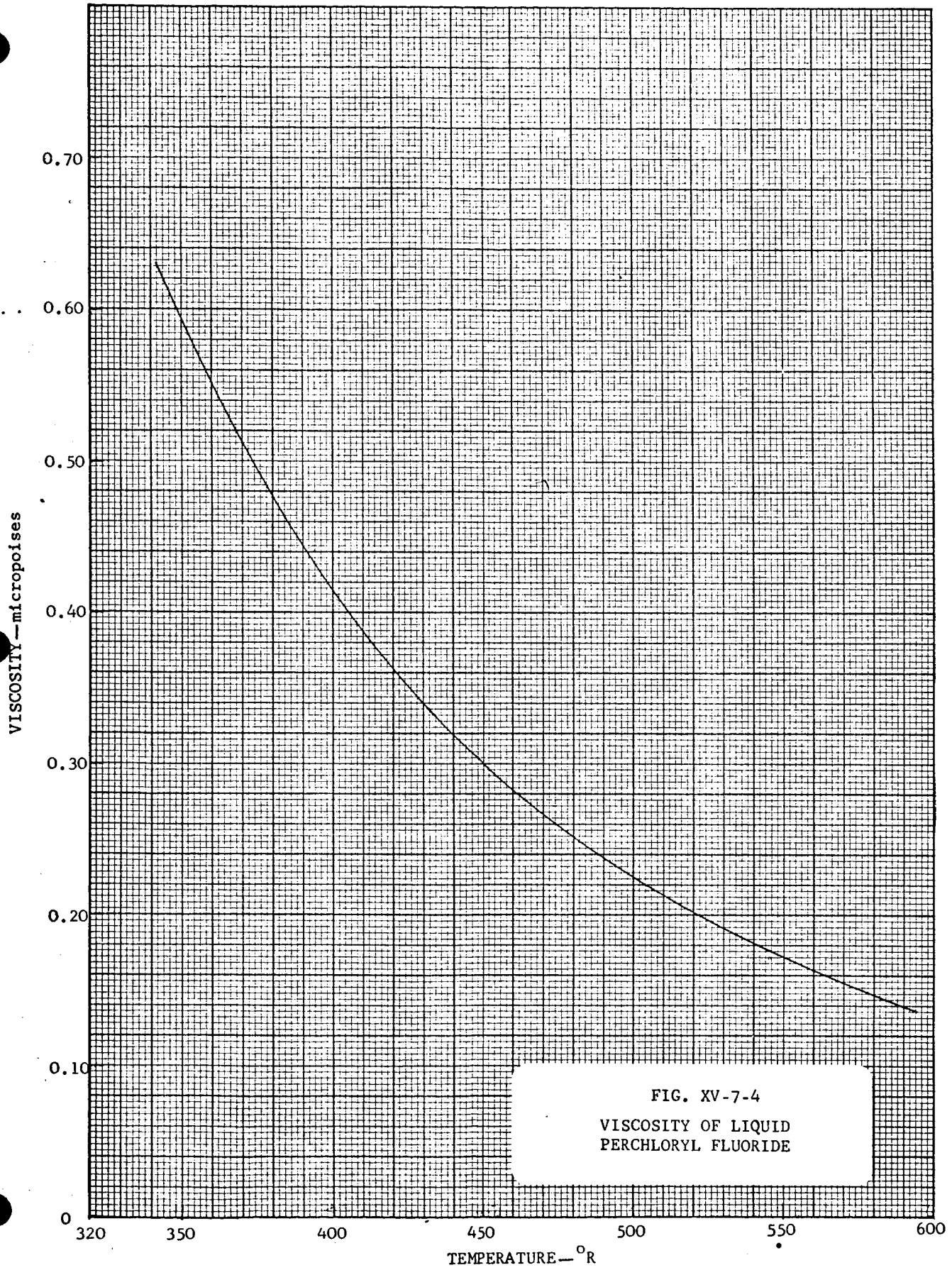

FIG. XV-7-4

VISCOSITY OF LIQUID
PERCHLORYL FLUORIDE

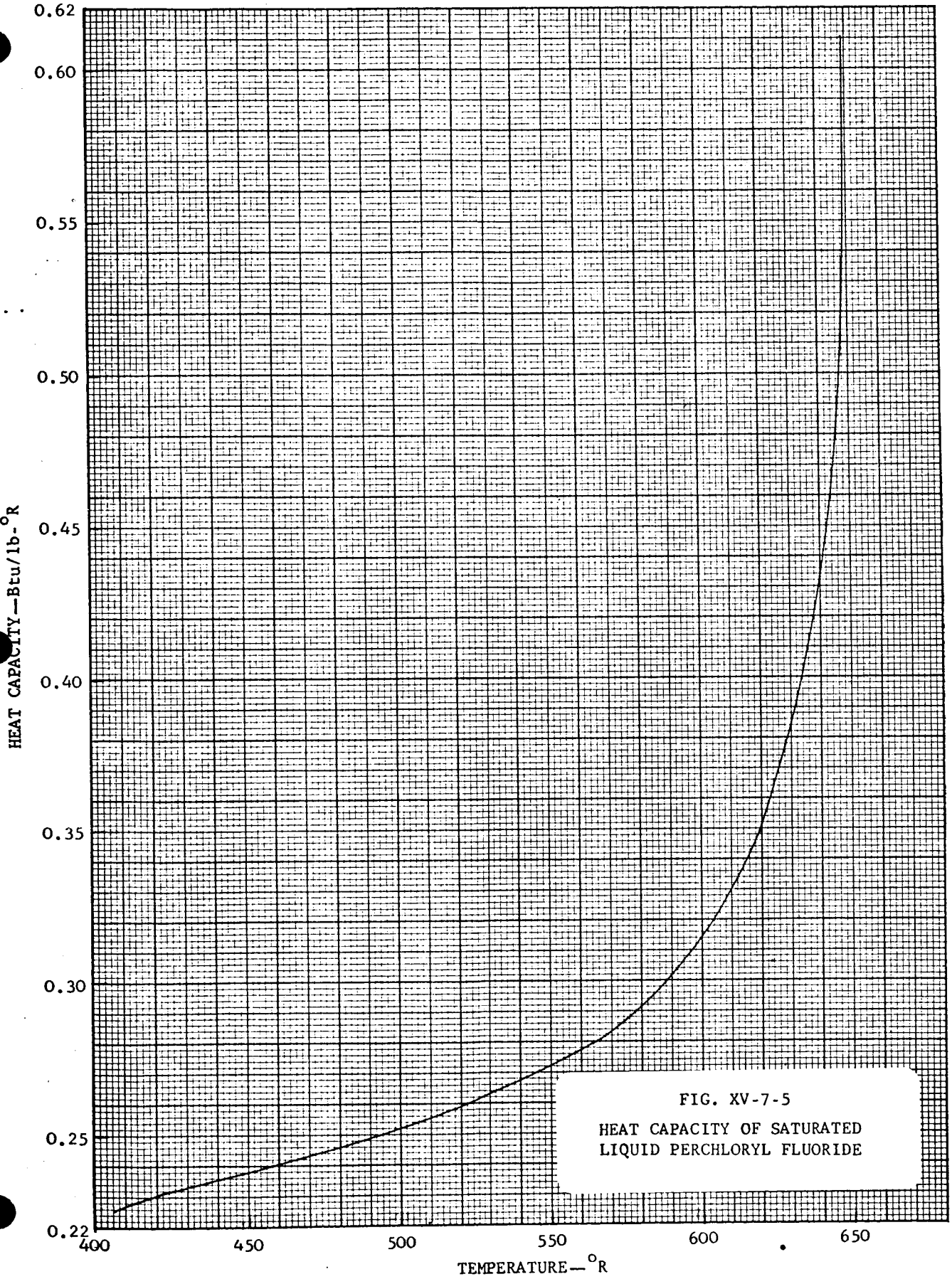

FIG. XV-7-5

HEAT CAPACITY OF SATURATED LIQUID PERCHLORYL FLUORIDE

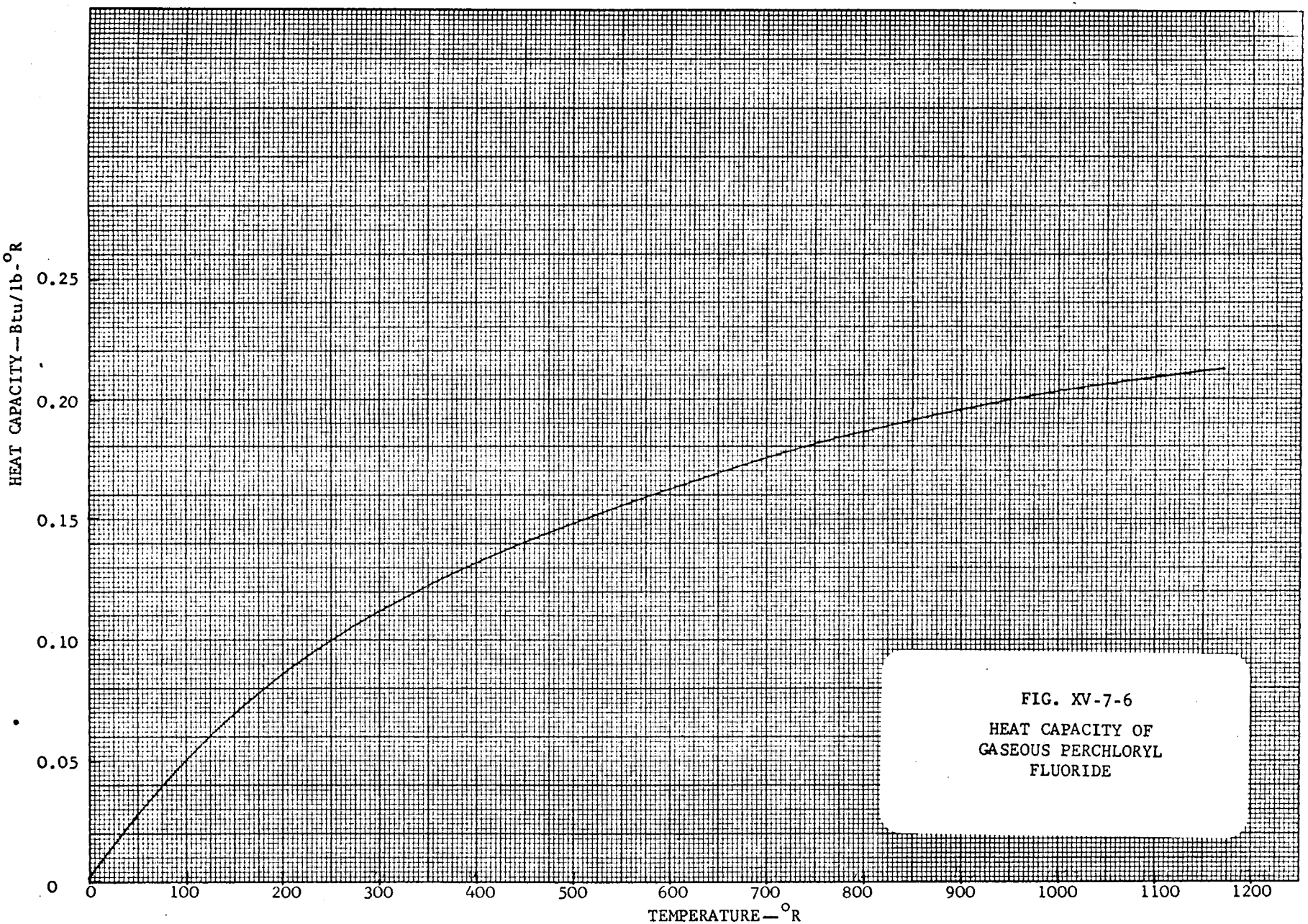

FIG. XV-7-6

HEAT CAPACITY OF GASEOUS PERCHLORYL FLUORIDE

XV-7 PERCHLORYL FLUORIDE REFERENCES

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Table XV-8-1

GENERAL PROPERTIES OF CHLORINE TRIFLUORIDE

PROPERTY	TEMPERATURE				PRESSURE			REF
	°C	°K	°F	°R	psia	atm	mm of Hg	
Melting Point								
Boiling Point	11.75	284.90	53.15	512.82				3
Triple Point	- 76.32	196.83	-105.38	354.29				3
Critical Temp.	174	447	345	804				3
Critical Press.					838	57		
Mol. Wt. 92.457								
Heat of Vaporization 71.17 cal/g or 128.1 Btu/lb at B.P.								3
Heat of Fusion 19.68 cal/g or 35.42 Btu/lb at triple point								3

Table XV-8-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR CHLORINE TRIFLUORIDE
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.893031	0.917001	674.509	13.0429
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0142164	0.0146888	10.8045	0.208925
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.493062	0.509445	374.727	7.24607
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00789803	0.00816043	6.00250	0.116069
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-8-2

VAPOR PRESSURE OF CHLORINE TRIFLUORIDE (Ref. 3)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
226.18	407.12	0.5619	283.00	509.40	13.56
231.64	416.95	0.8278	284.90	512.82	14.70
237.56	427.61	1.230	285.39	513.70	15.00
240.01	432.02	1.437	286.93	516.47	16.01
242.40	436.32	1.671	290.61	523.10	18.60
245.98	442.76	2.081	290.91	523.64	18.83
249.00	448.20	2.477	294.17	529.51	21.417
253.90	457.02	3.278	298.12	536.62	24.935
255.52	459.94	3.578	298.82	537.88	25.616
259.22	466.60	4.376	302.70	544.86	29.597
263.43	474.17	5.441	313.15	563.67	42.837
267.52	481.54	6.672	323.15	581.67	59.436
271.57	488.83	8.111	333.15	599.67	80.641
275.52	495.94	9.739			
279.55	503.19	11.67			

(See Figure XV-8-1)

Table XV-8-3

DENSITY OF LIQUID CHLORINE TRIFLUORIDE (Ref. 2)

TEMPERATURE		DENSITY
°K	°R	lb/ft³
273.15	491.67	117.70
283.15	509.67	115.84
285.15	513.67	115.50
288.15	518.67	114.89
293.15	527.67	113.93
298.15	536.67	112.96
303.15	545.67	111.97
308.15	554.67	110.98
313.15	563.67	109.98
318.15	572.67	108.95
323.15	581.67	107.92
333.15	599.67	105.83

(See Figure XV-8-2)

Table XV-8-4

SURFACE TENSION OF LIQUID CHLORINE TRIFLUORIDE IN CONTACT WITH ITS VAPOR (Ref. 1)

TEMPERATURE		SURFACE TENSION	TEMPERATURE		SURFACE TENSION
°K	°R	dynes/cm	°K	°R	dynes/cm
273.15	491.67	26.6	298.65	537.57	22.7
275.65	496.17	26.3	298.75	537.75	22.8
277.15	498.87	26.0	304.15	547.47	22.2
282.05	507.69	25.35	310.75	559.35	20.4
282.15	507.87	25.15	311.15	560.07	20.3
287.75	517.95	24.3	313.55	564.39	20.5
291.55	524.79	24.05	315.15	567.27	20.0
293.75	528.75	23.1	320.15	576.27	19.1
294.35	529.83	23.3	323.05	581.49	18.7
298.25	536.85	22.8			

(See Figure XV-8-3)

Table XV-8-5

VISCOSITY OF LIQUID CHLORINE TRIFLUORIDE (Ref. 1)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	millipoises
284.90	513.02	4.78
288.15	520.67	4.60
290.85	523.53	4.47
292.55	526.59	4.38
293.15	527.67	4.35
298.15	536.67	4.12
303.15	545.67	3.90
308.15	554.67	3.70
313.15	563.67	3.51
318.15	572.67	3.33
323.15	581.67	3.16

(See Figure XV-8-4)

Table XV-8-6

THERMAL CONDUCTIVITY OF GASEOUS CHLORINE TRIFLUORIDE (Ref. 4)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
100	180	0.00165
200	360	0.00436
300	540	0.00794
400	720	0.0116
500	900	0.0151
600	1080	0.0184

(See Figure XV-8-5)

Table XV-8-7

HEAT CAPACITIES OF SOLID AND LIQUID
CHLORINE TRIFLUORIDE (Ref. 3)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb°R	°K	°R	Btu/lb-°R
14.04	25.27	0.0111	108.47	195.25	0.1390
15.28	27.50	0.0133	111.35	200.43	0.1409
16.60	29.88	0.0162	119.00	214.20	0.1471
18.03	32.45	0.0188	126.54	227.77	0.1532
20.10	36.18	0.0230	134.34	241.81	0.1592
22.74	40.93	0.0289	141.87	255.37	0.1653
25.88	46.58	0.0363	149.15	268.47	0.1707
29.11	52.46	0.0438	156.22	281.20	0.1761
32.59	58.66	0.0514	160.61	289.10	0.1794
36.42	65.56	0.0593	163.57	294.43	0.1820
40.67	73.21	0.0673	167.80	302.04	0.1847
45.88	82.58	0.0763	171.20	308.16	0.1878
51.29	92.32	0.0842	175.20	315.36	0.1907
51.89	93.40	0.0849	178.62	321.52	0.1934
56.27	101.29	0.0907	180.60	325.08	0.1951
56.30	101.34	0.0911	182.33	328.19	0.1970
62.07	111.73	0.0981	184.96	332.93	0.1997
67.82	122.08	0.1038	187.56	937.61	0.2031
73.16	131.69	0.1092	196.84	354.31	0.2074
78.96	142.13	0.1149		Liquid	
82.94	149.29	0.1185	196.84	354.31	0.2886
88.44	159.19	0.1243	202.76	364.97	0.2894
90.94	163.69	0.1261	204.83	368.69	0.2896
95.62	172.12	0.1301	207.69	373.84	0.2900
97.01	174.62	0.1308	216.53	389.75	0.2914
102.84	185.11	0.1344	219.84	395.71	0.2916
103.44	186.19	0.1349	226.95	408.51	0.2926
			237.83	428.09	0.2944
			248.61	447.50	0.2961
			259.30	466.74	0.2986
			269.86	485.75	0.3011
			278.25	500.85	0.3031

(See Figure XV-8-6)

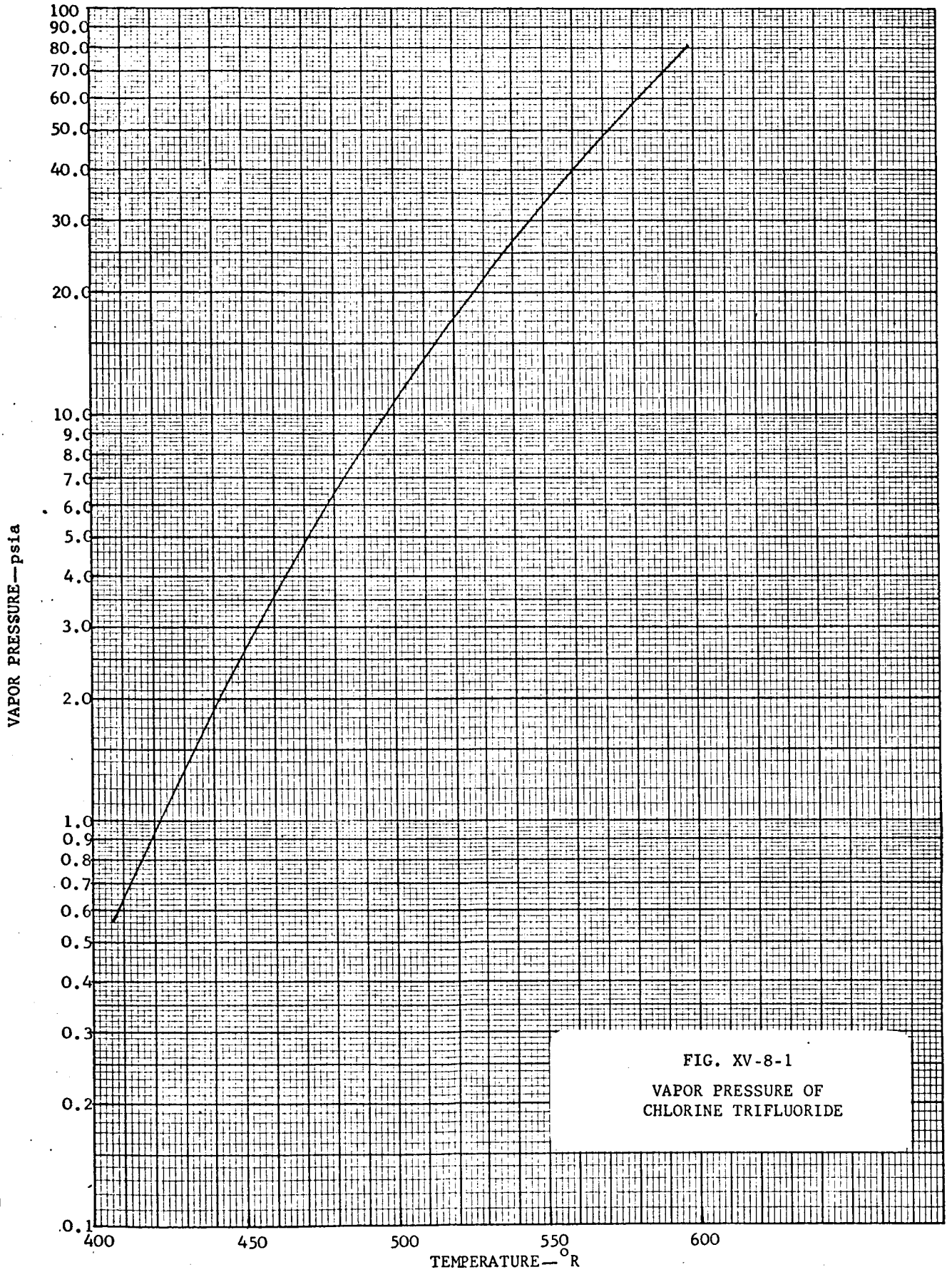

FIG. XV-8-1

VAPOR PRESSURE OF CHLORINE TRIFLUORIDE

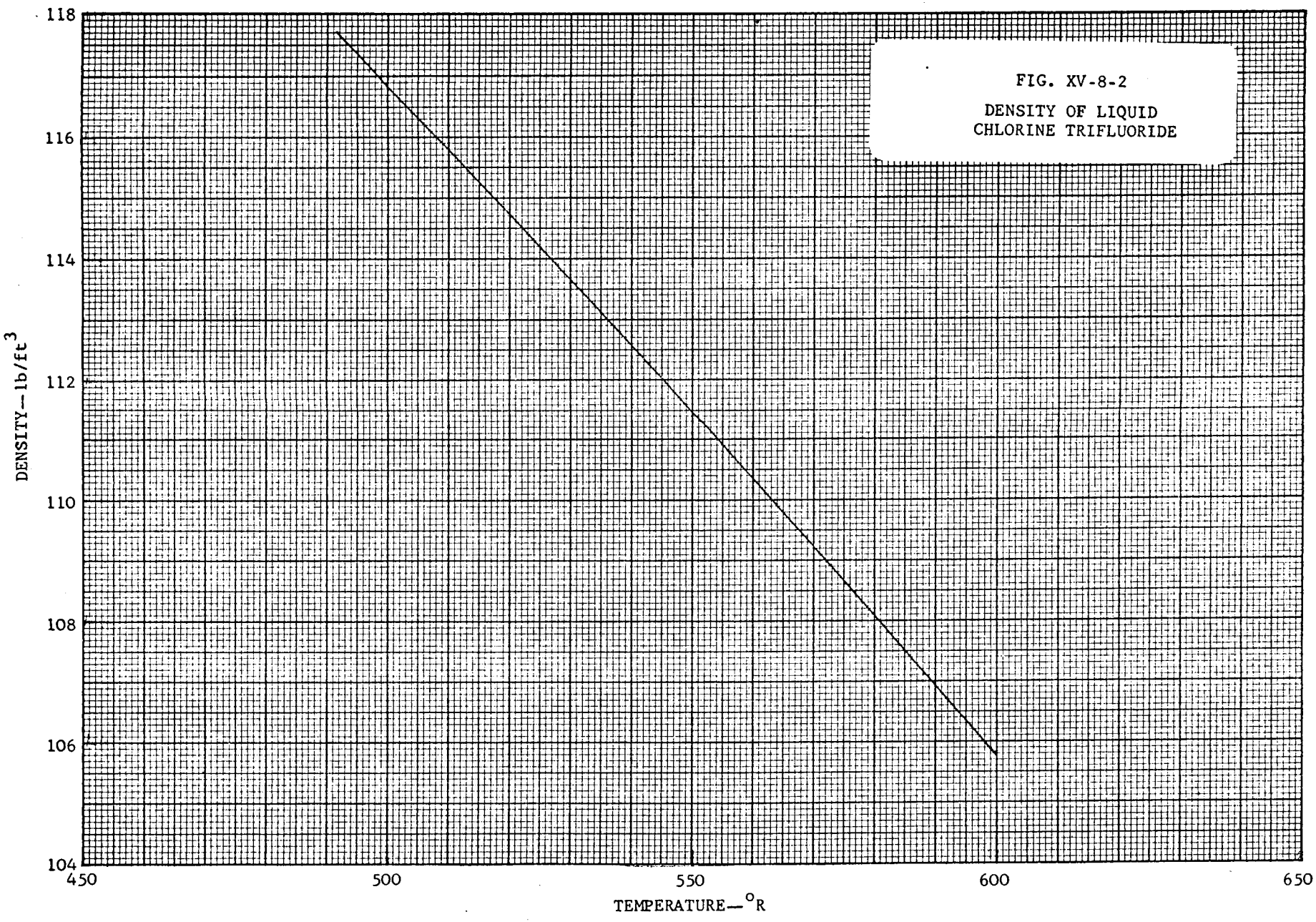

FIG. XV-8-2

DENSITY OF LIQUID
CHLORINE TRIFLUORIDE

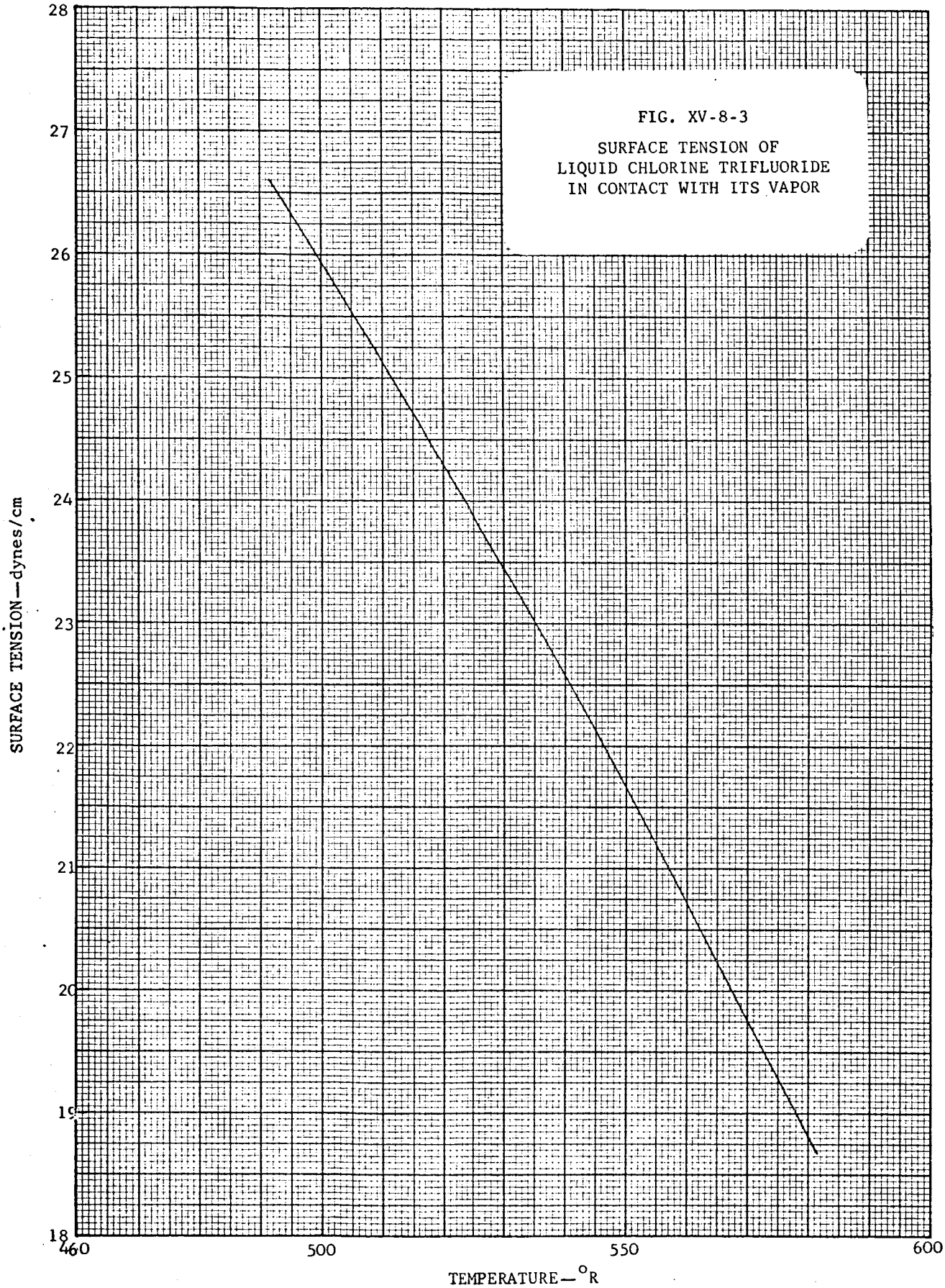

FIG. XV-8-3

SURFACE TENSION OF
LIQUID CHLORINE TRIFLUORIDE
IN CONTACT WITH ITS VAPOR

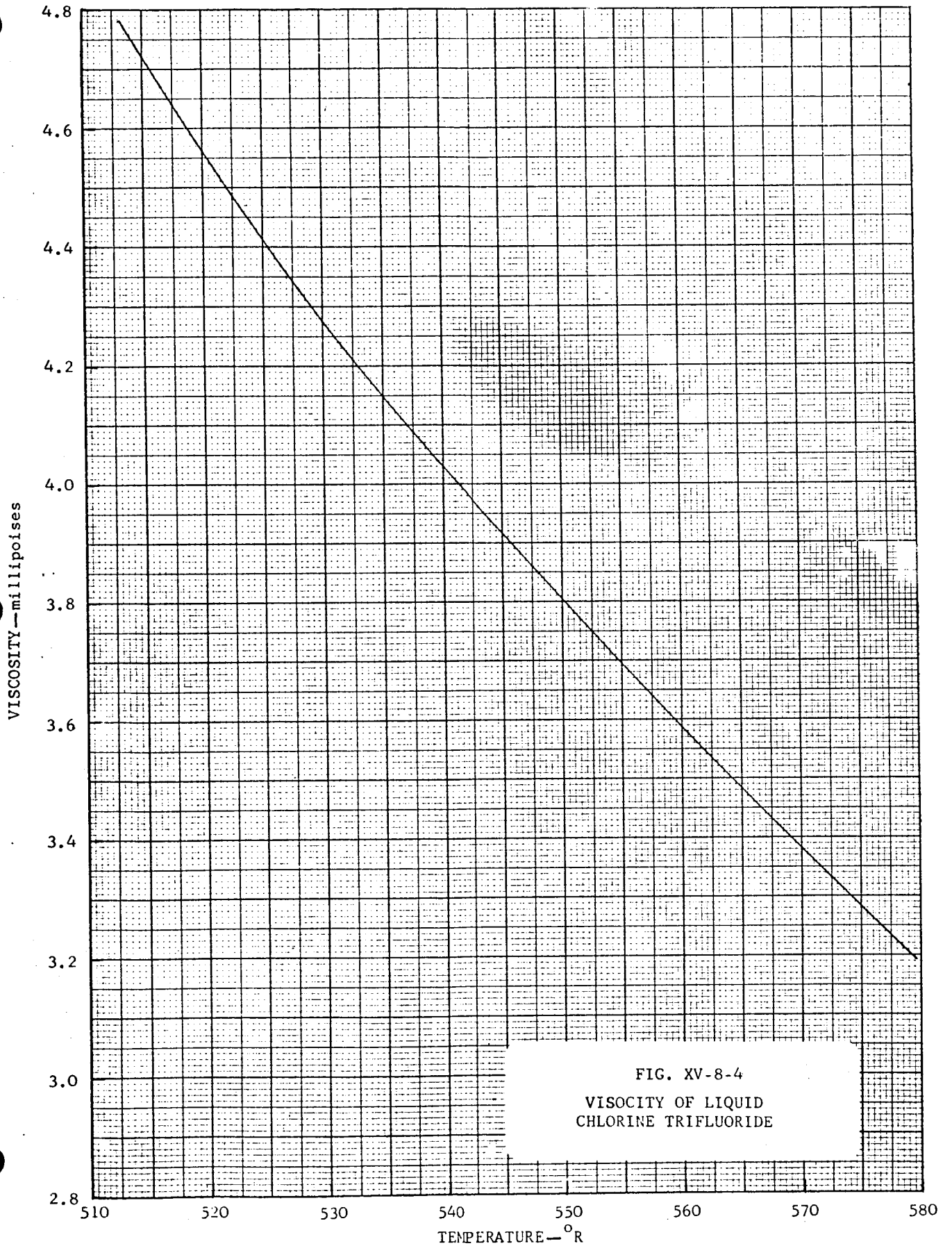

FIG. XV-8-4

VISOCITY OF LIQUID
CHLORINE TRIFLUORIDE

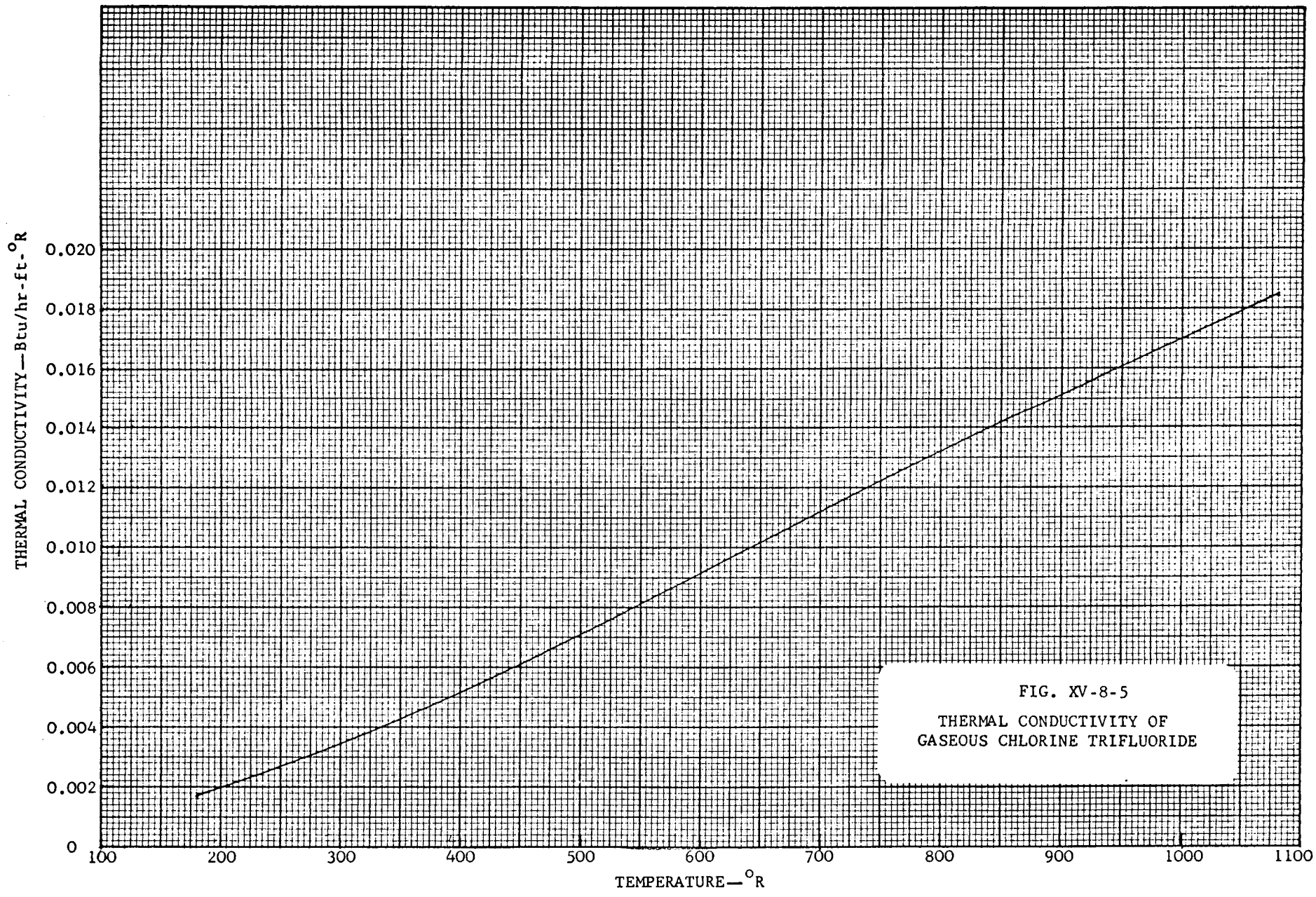

FIG. XV-8-5

THERMAL CONDUCTIVITY OF GASEOUS CHLORINE TRIFLUORIDE

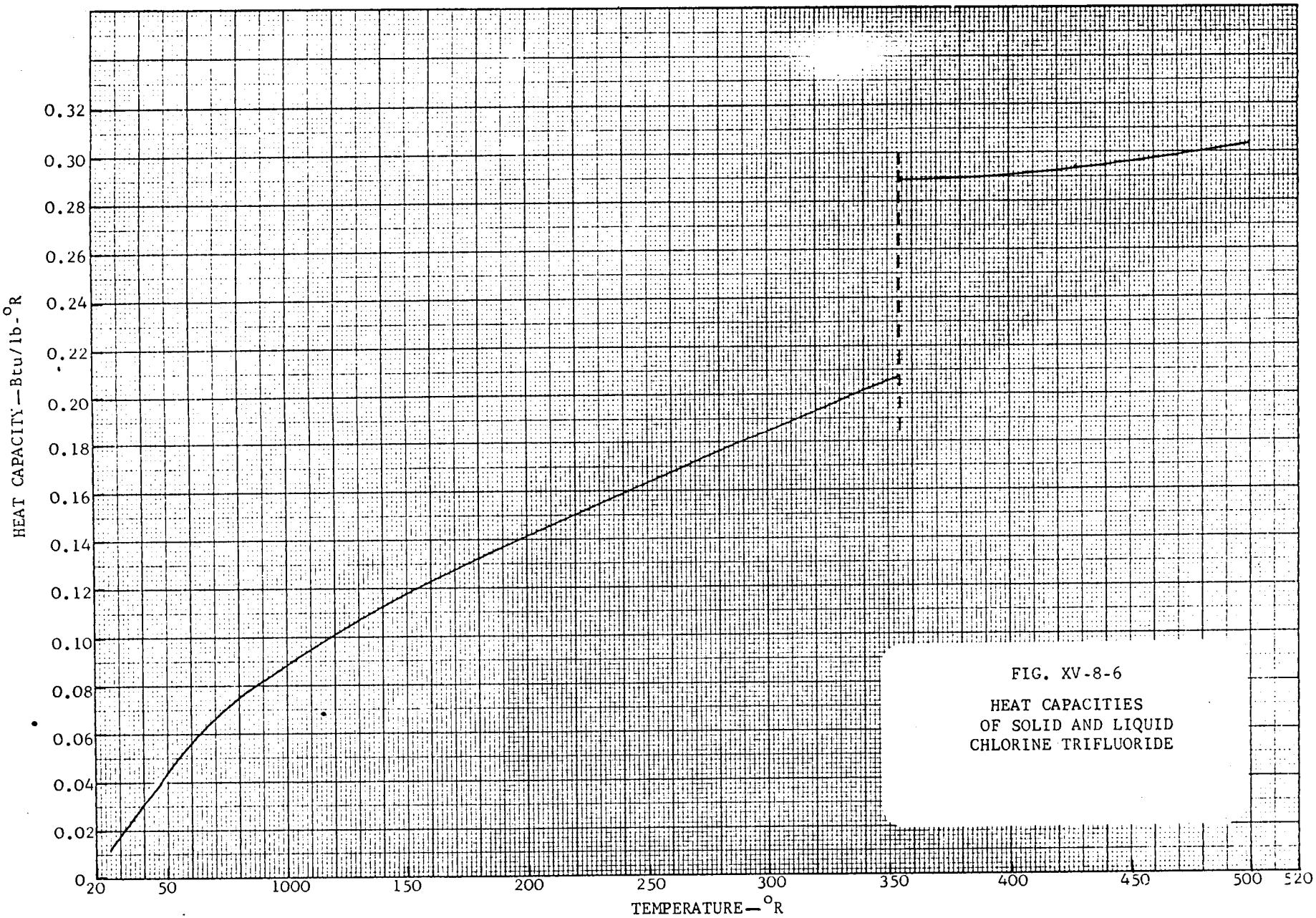

FIG. XV-8-6

HEAT CAPACITIES
OF SOLID AND LIQUID
CHLORINE TRIFLUORIDE

XV-8 CHLORINE TRIFLUORIDE REFERENCES

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Table XV-9-1

GENERAL PROPERTIES OF HYDRAZINE

PROPERTY	TEMPERATURE				PRESSURE			REF
	°C	°K	°F	°R	psia	atm	mm of Hg	
Melting Point*	1.6	274.75	33.91	493.58				4
Boiling Point	114.15	387.3	237.47	697.14				2
Triple Point								
Critical Temp.	380	653	716	1176				3
Critical Press.					2131	145	110,200	3
Mol Wt. 32.05								
Heat of Vaporization 333.85 cal/g or 600.9 Btu/lb at 25°C								5
Heat of Fusion 94.38 cal/g or 169.9 Btu/lb								5

* 99.6%

Table XV-9-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR HYDRAZINE

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.56027	2.64534	1945.80	37.6259
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0410112	0.0423738	31.1685	0.602702
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.42237	1.46963	1081.00	20.9033
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0227840	0.0235410	17.3159	0.334833
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-9-2

VAPOR PRESSURE OF ANHYDROUS HYDRAZINE

(Ref. 5)

TEMPERATURE		PRESSURE	
°K	°R	psia	mm Hg
273.2	491.7	0.0516	2.67
288.2	518.7	0.148	7.64
293.2	527.7	0.204	10.53
298.2	536.7	0.277	14.35
303.2	545.7	0.373	19.31
308.2	554.7	0.497	25.70
313.2	563.7	0.654	33.83
318.2	572.7	0.853	44.10
323.2	581.7	1.101	56.93
328.2	590.67	1.408	72.84
333.2	599.67	1.787	92.40
338.2	608.7	2.248	116.26
343.2	617.7	2.807	145.16

(See Figure XV-9-1)

Table XV-9-3

DENSITY OF LIQUID HYDRAZINE (Ref. 1)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
^oK	^oR	lb/ft^3	^oK	^oR	lb/ft^3
273.2	491.8	64.047	333.2	599.8	60.613
283.2	509.8	63.485	343.2	617.8	60.123
293.2	527.8	62.917	353.2	635.8	59.440
303.2	545.8	62.349	368.2	662.8	58.541
313.2	563.8	61.774			
323.2	581.8	61.200			

(See Figure XV-9-2)

Table XV-9-4

VISCOSITY OF HYDRAZINE (Ref. 1)

TEMPERATURE		KINEMATIC VISCOSITY	ABSOLUTE VISCOSITY
^oK	^oR	centistokes	centipoises
288.15	518.67	1.015	1.0276
298.15	536.67	0.8705	0.8733
308.15	554.67	0.7568	0.7523
318.15	572.67	0.6719	0.6618
328.15	590.67	0.6003	0.5856
338.15	608.67	0.5434	0.5250
348.15	626.67	0.4969	0.4754
358.15	644.67	0.4557	0.4313
368.15	662.67	0.4236	0.3972

(See Figure XV-9-3)

Table XV-9-5

HEAT CAPACITY OF LIQUID HYDRAZINE (Ref. 5)

TEMPERATURE		HEAT CAPACITY, C_p
^oK	^oR	Btu/lb-^oR
274.69	494.4	0.727
280	504.0	0.729
290	522.0	0.734
298	536.4	0.737
300	540.0	0.738
310	558.0	0.743
320	576.0	0.748
330	594.0	0.753
340	612.0	0.759

(See Figure XV-9-4)

Table XV-9-6

HEAT CAPACITY OF GASEOUS HYDRAZINE (Ref. 5)

TEMPERATURE		HEAT CAPACITY, C_p
^oK	^oR	Btu/lb-^oR
298.2	536.8	0.393
300.0	540.0	0.393
400.0	720.0	0.471
500.0	900.0	0.527
600.0	1080.0	0.571

(See Figure XV-9-5)

Table XV-9-7

HEAT CAPACITY OF HYDRAZINE AT CONSTANT PRESSURE (Ref. 5)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb-°R	°K	°R	Btu/lb-°R
12	21.6	0.00218	90	162	0.20966
13	23.4	0.00296	95	171	0.22027
14	25.2	0.00359	100	180	0.23010
15	27.0	0.00437	110	198	0.24898
16	28.8	0.00515	120	216	0.26645
17	30.6	0.00640	130	234	0.28298
18	32.4	0.00780	140	252	0.29858
19	34.2	0.00936	150	270	0.31340
20	36.0	0.01092	160	288	0.33072
25	45	0.02122	170	306	0.34117
30	54	0.03448	180	324	0.35443
35	63	0.05008	190	342	0.36738
40	72	0.06646	200	360	0.38048
45	81	0.08346	210	378	0.39343
50	90	0.10031	220	396	0.40654
55	99	0.11669	230	414	0.41948
60	108	0.13198	240	432	0.43259
65	117	0.14664	250	450	0.44554
70	126	0.16052	260	468	0.45864
75	135	0.17348	270	486	0.47174
80	144	0.18611	274.69	494.44	0.47767
85	153	0.19828			

(See Figure XV-9-6)

Table XV-9-8

THERMAL CONDUCTIVITY OF HYDRAZINE (Ref. 6)

(Smoothed Data)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
280	504.0	0.2090
350	630.0	0.1972
400	720.0	0.1885
422	760.0	0.1855
477	858.6	0.1770
533	959.4	0.1690

(See Figure XV-9-7)

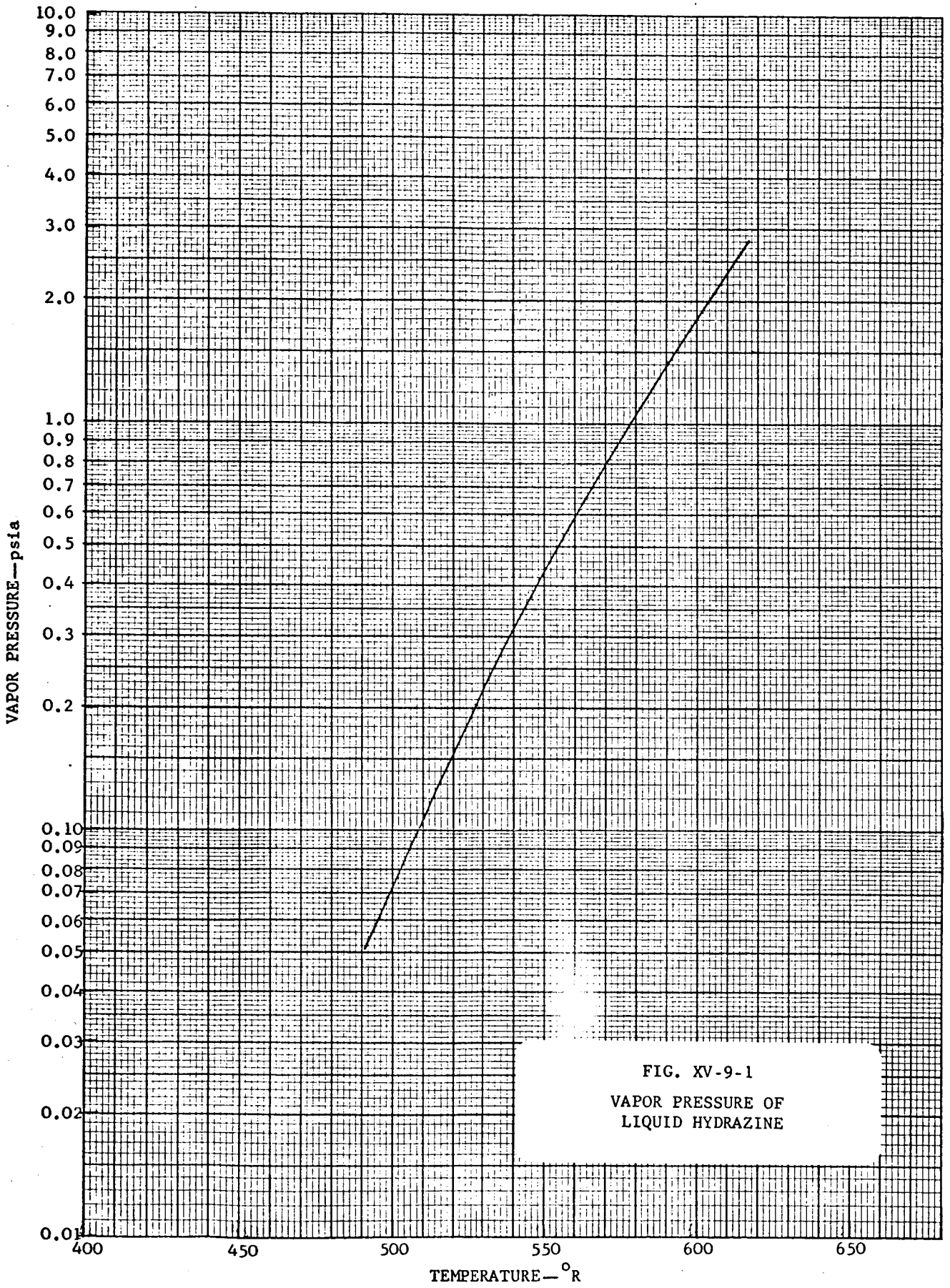

FIG. XV-9-1

VAPOR PRESSURE OF LIQUID HYDRAZINE

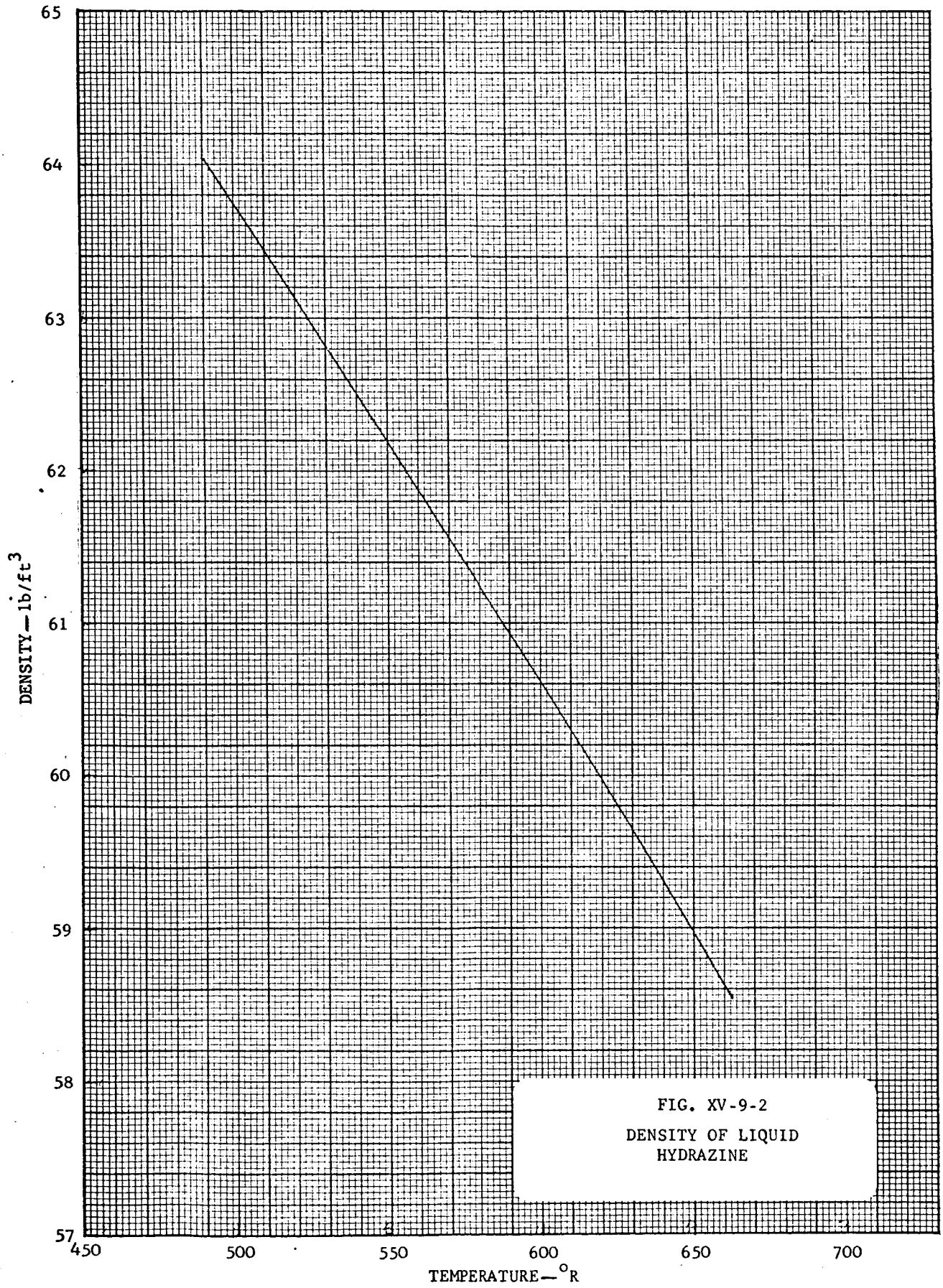

FIG. XV-9-2

DENSITY OF LIQUID HYDRAZINE

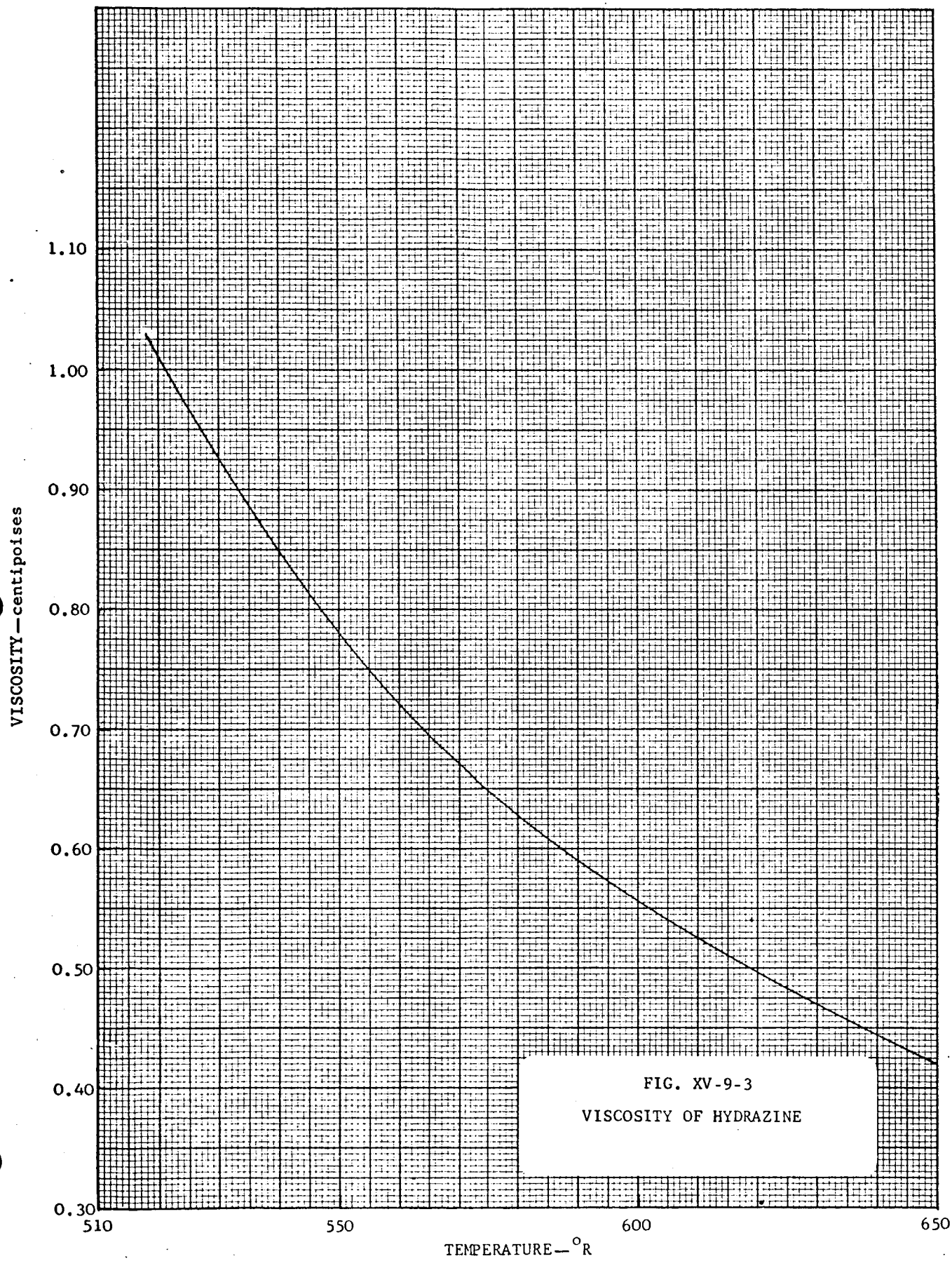

FIG. XV-9-3

VISCOSITY OF HYDRAZINE

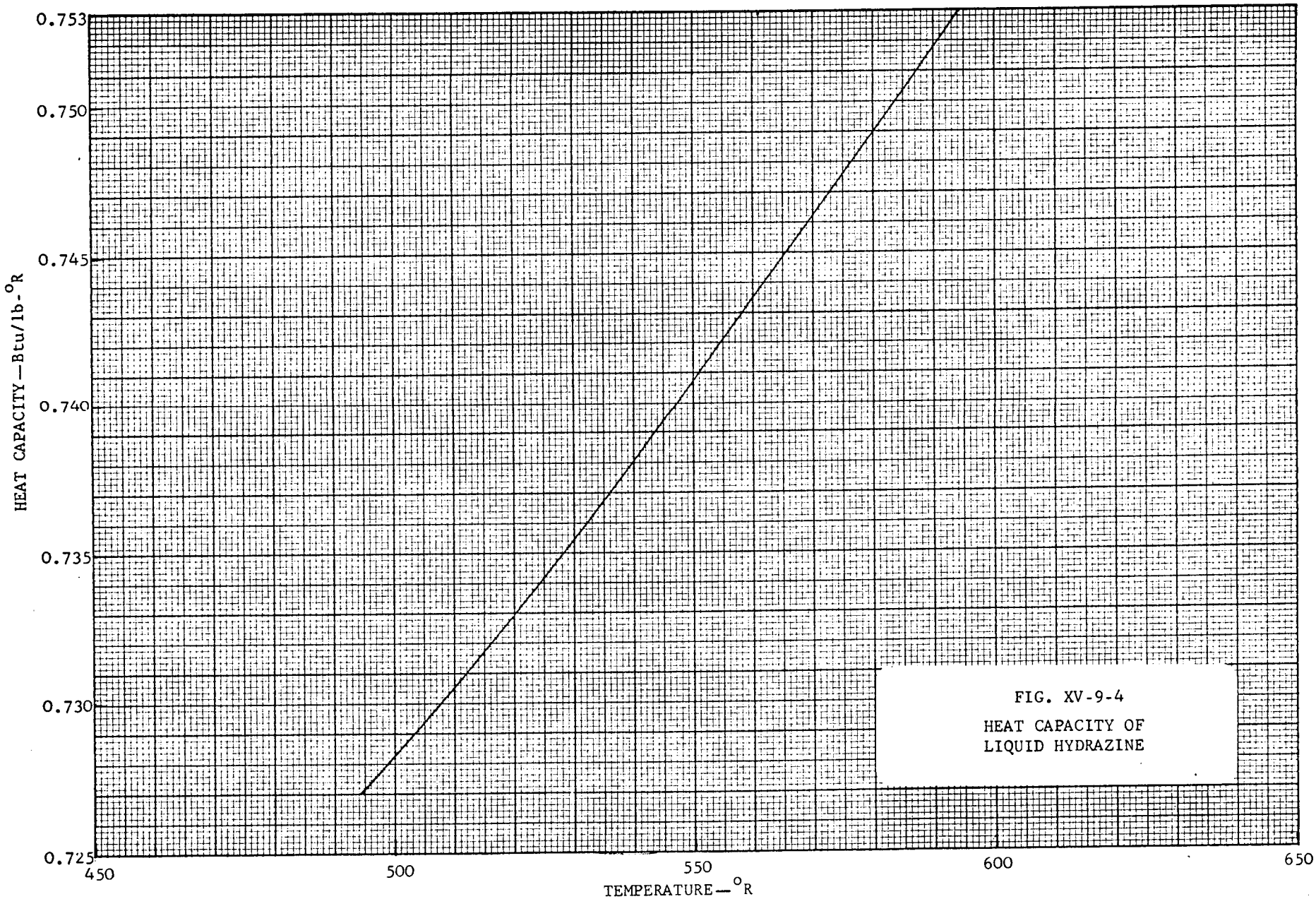

FIG. XV-9-4

HEAT CAPACITY OF
LIQUID HYDRAZINE

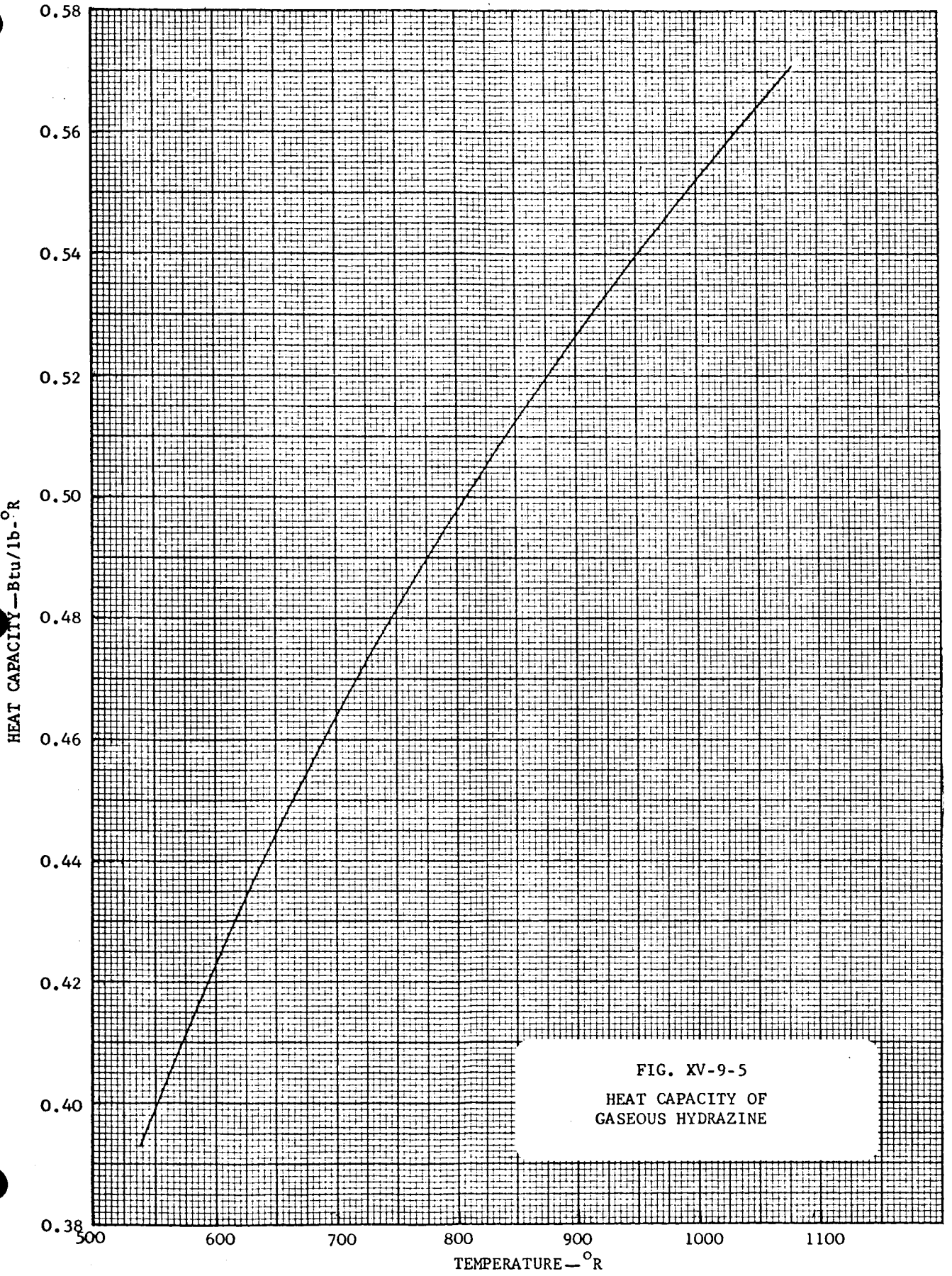

FIG. XV-9-5

HEAT CAPACITY OF GASEOUS HYDRAZINE

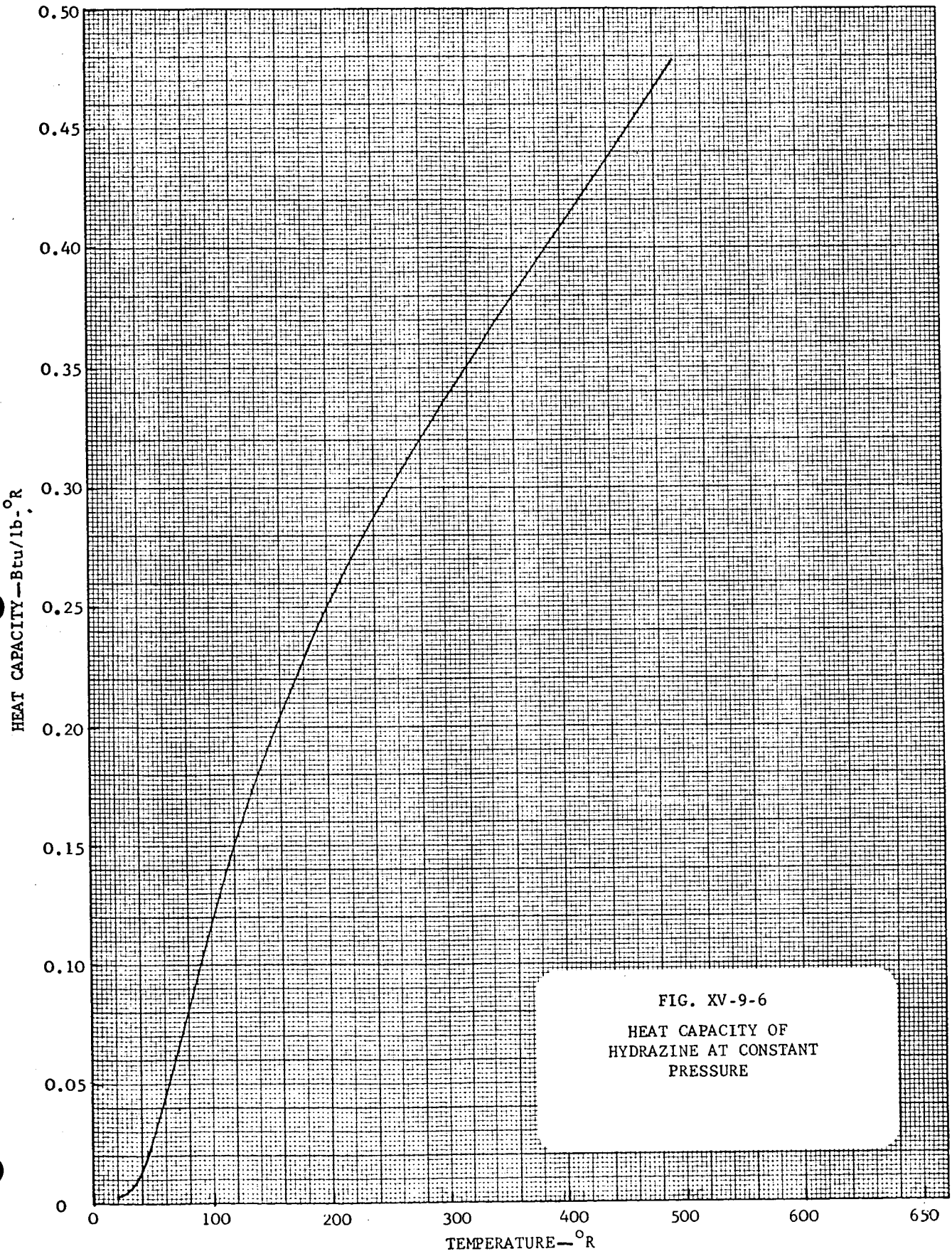

FIG. XV-9-6

HEAT CAPACITY OF HYDRAZINE AT CONSTANT PRESSURE

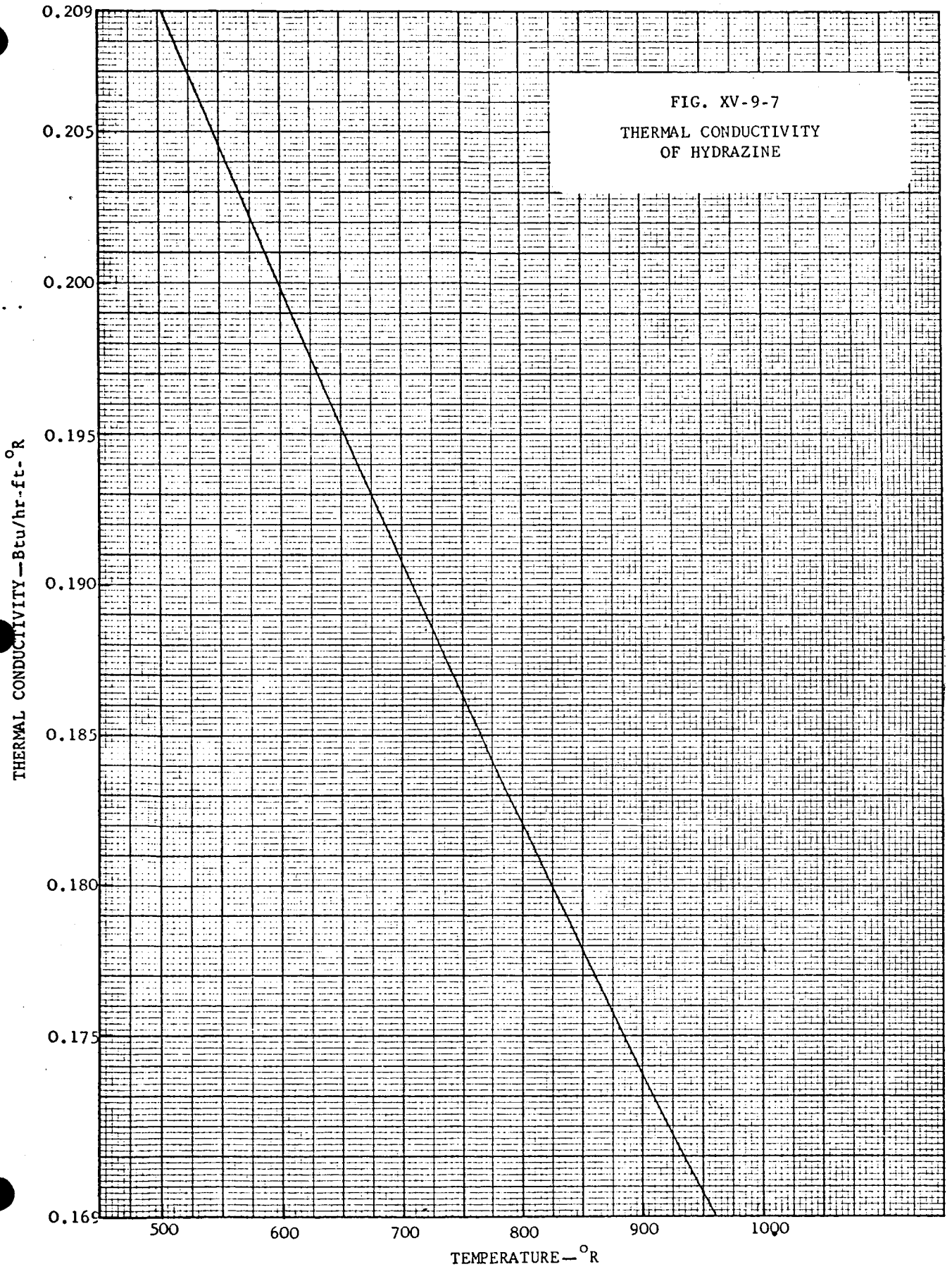

FIG. XV-9-7

THERMAL CONDUCTIVITY OF HYDRAZINE

XV-9 HYDRAZINE REFERENCES

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Table XV-10-1

GENERAL PROPERTIES OF NITROGEN (IV) OXIDE

PROPERTY	TEMPERATURE				PRESSURE			REF
	°C	°K	°F	°R	psia	atm	mm of Hg	
Melting Point	- 11.2	261.95	11.84	471.51				1
Boiling Point	21.15	294.30	70.13	529.74				1
Triple Point	- 11.20	261.95	11.84	471.51				1
Critical Temp.	158.2	431.35	316.76	776.43				2
Critical Press.					1469.0	99.96		2
Mol. Wt. 46.01 (NO_2)								
Heat of Vaporization. 99.00 cal/g at b.p. or 178.20 Btu/lb								1
Heat of Fusion. 38.06 cal/g or 68.51 Btu/lb at triple point								1

Table XV-10-2

VAPOR PRESSURE OF $N_2O_4 \rightleftharpoons 2\ NO_2$ SYSTEM (Ref. 1,3)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
243.15	437.67	0.508	333.15	599.67	74.12
253.15	455.67	1.279	388.70	609.67	91.06
261.95	471.51	2.703 (m.p.)	344.26	619.67	111.24
263.15	473.67	2.893	349.82	629.67	135.14
273.15	491.67	5.078	355.37	639.67	163.29
283.15	509.67	8.555	360.93	649.67	196.35
293.15	527.67	13.925	366.48	659.67	235.01
294.30	529.74	14.696 (b.p.)	372.04	669.67	281.56
294.26	529.67	14.78	377.59	679.67	332.8
299.82	539.67	18.98	383.15	689.67	393.2
305.37	549.67	24.21	388.70	699.67	463.3
310.93	559.67	30.69	394.26	709.67	543.9
316.48	569.67	38.62	399.82	719.67	636.3
322.04	579.67	48.24			
327.59	589.67	59.98			

(See Figure XV-10-1)

Table XV-10-3

DENSITY OF EQUILIBRIUM

$N_2O_4 \rightleftharpoons 2\ NO_2$ MIXTURES

(Ref. 2)

TEMPERATURE		DENSITY--lb/ft^3	
^oK	^oR	Saturated Liquid	Saturated Gas
294.30	529.67	89.85	0.212
299.82	539.67	89.13	0.269
305.37	549.67	88.34	0.322
310.93	559.67	87.41	0.397
316.48	569.67	86.58	0.488
322.04	579.67	85.69	0.497
327.59	589.67	84.82	0.731
333.15	599.67	83.89	0.888
338.70	609.67	83.13	1.075
344.26	619.67	82.03	1.293
349.82	629.67	81.17	1.554
355.37	639.37	80.06	1.855
360.93	649.67	78.99	2.197
366.48	659.67	77.82	2.618
372.04	660.67	76.45	3.094
377.59	679.67	75.02	3.646
383.15	689.67	73.42	4.310
388.70	699.67	71.79	5.089
394.26	709.67	69.88	6.013
399.82	719.67	67.84	7.148

(See Figure XV-10-2
Figure XV-10-3)

Table XV-10-4

SPECIFIC HEAT OF THE $N_2O_4 \rightleftharpoons 2\ NO_2$ SYSTEM

AT CONSTANT PRESSURE (Ref. 1)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
^oK	^oR	Btu/lb--^oR	^oK	^oR	Btu/lb--^oR
20	36	0.02206	170	306	0.2147
30	54	0.04890	180	324	0.2224
40	72	0.07455	190	342	0.2302
50	90	0.09455	200	360	0.2382
60	108	0.1109	210	378	0.2463
70	126	0.1245	220	396	0.2544
80	144	0.1365	230	414	0.2625
90	162	0.1476	240	432	0.2705
100	180	0.1577	250	450	0.2785
110	198	0.1667	260	468 (solid)	0.2865
120	216	0.1755	270	486 (liquid)	0.3579
130	234	0.1837	280	504	0.3617
140	252	0.1916	290	522	0.3664
150	270	0.1995			
160	288	0.2072			

(See Figure XV-10-4)

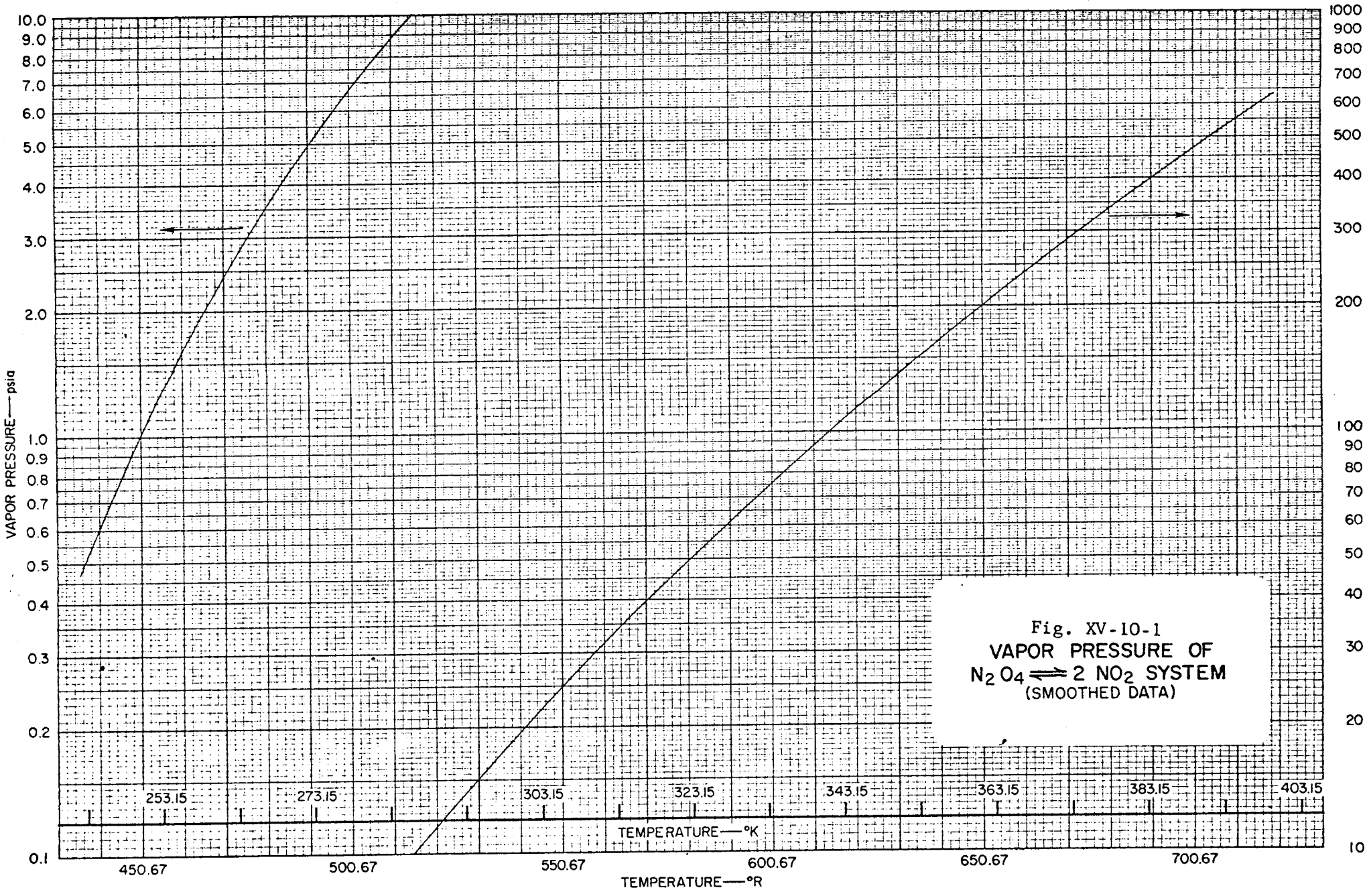

Fig. XV-10-1
VAPOR PRESSURE OF
$N_2O_4 \rightleftharpoons 2\ NO_2$ SYSTEM
(SMOOTHED DATA)

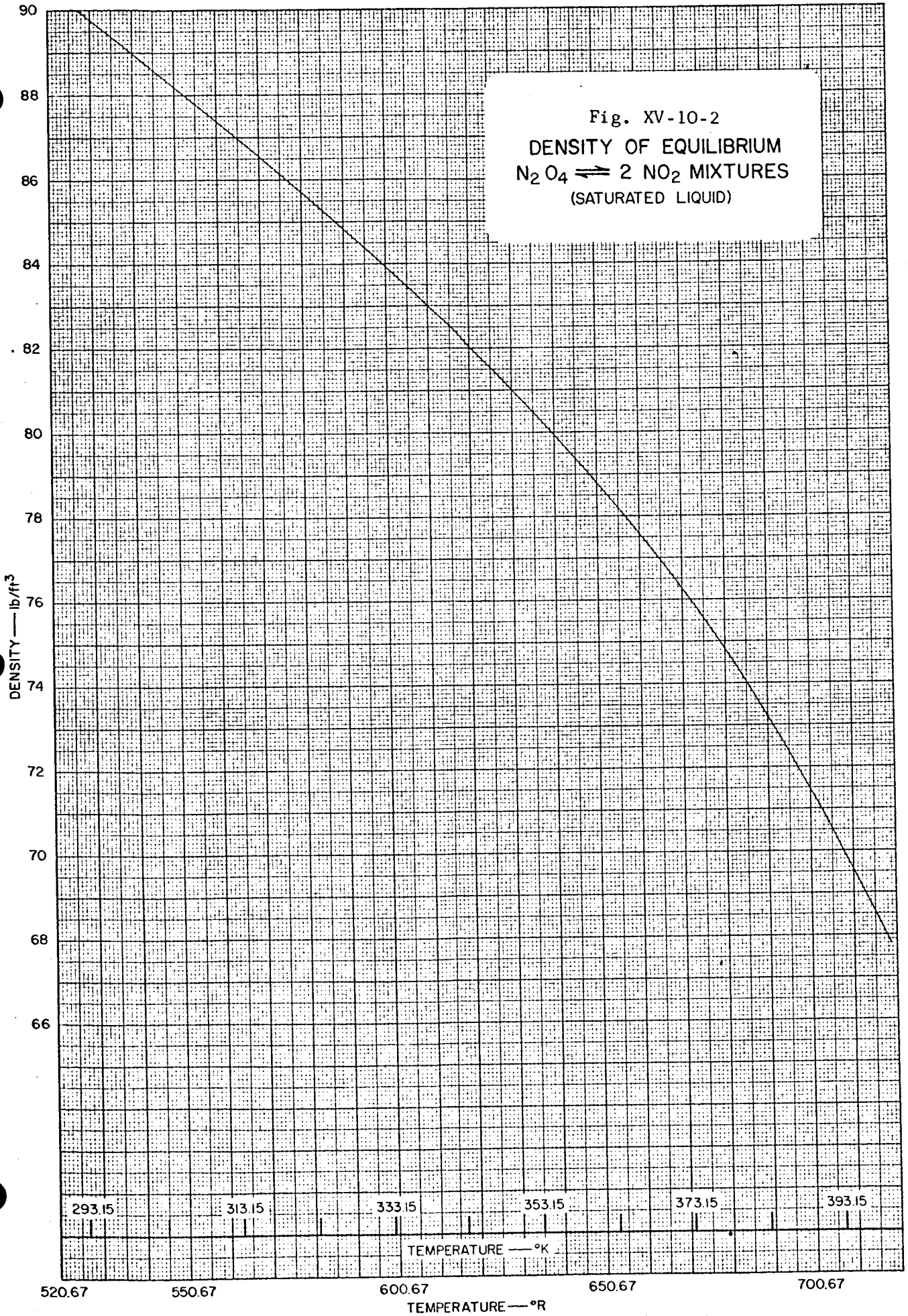
Fig. XV-10-2
DENSITY OF EQUILIBRIUM
$N_2O_4 \rightleftharpoons 2\ NO_2$ MIXTURES
(SATURATED LIQUID)
DENSITY — lb/ft³
90
88
86
84
82
80
78
76
74
72
70
68
66
293.15
313.15
333.15
353.15
373.15
393.15
TEMPERATURE — °K
520.67
550.67
600.67
650.67
700.67
TEMPERATURE — °R

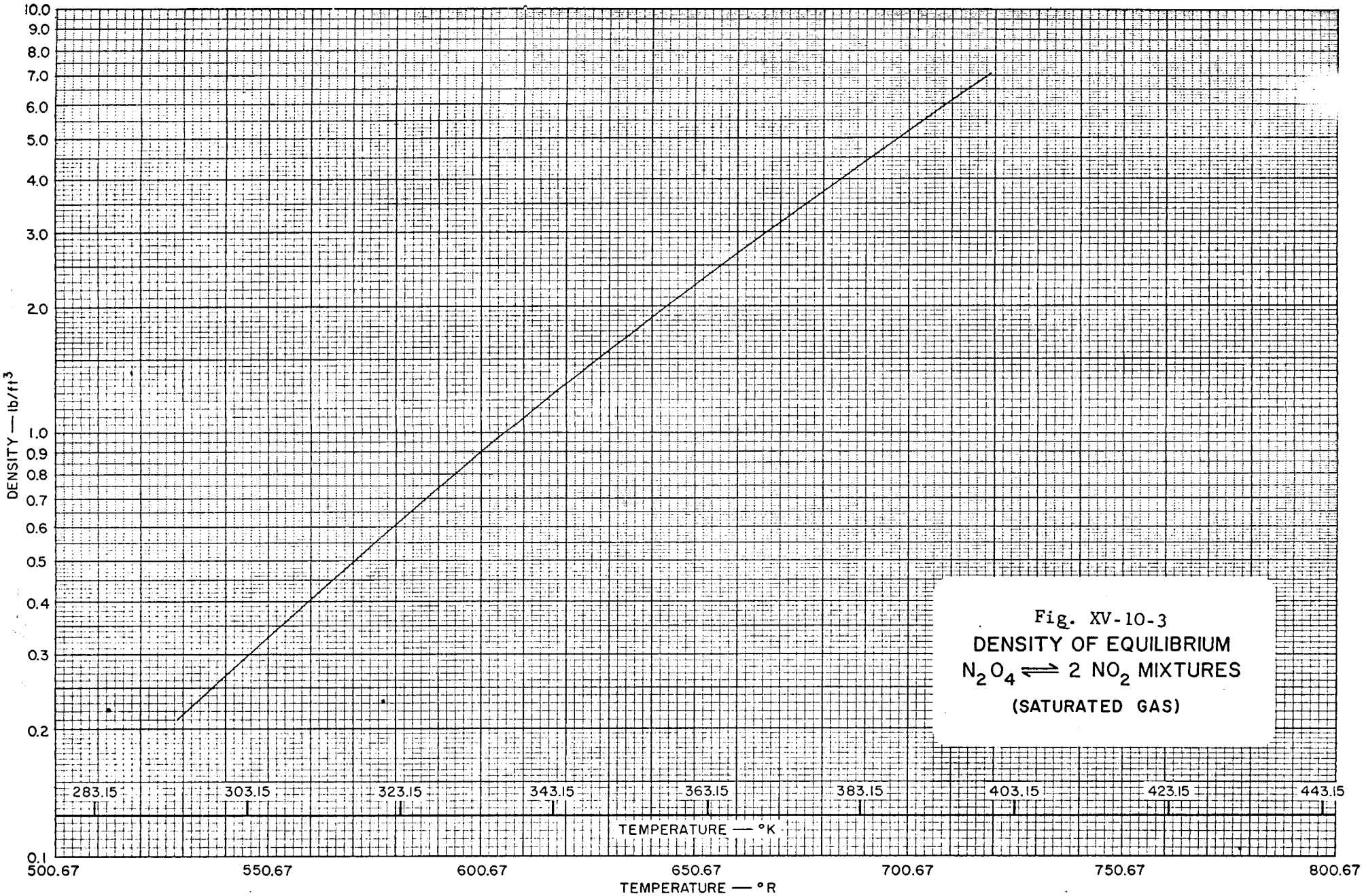

Fig. XV-10-3
DENSITY OF EQUILIBRIUM
$N_2O_4 \rightleftharpoons 2\ NO_2$ MIXTURES
(SATURATED GAS)

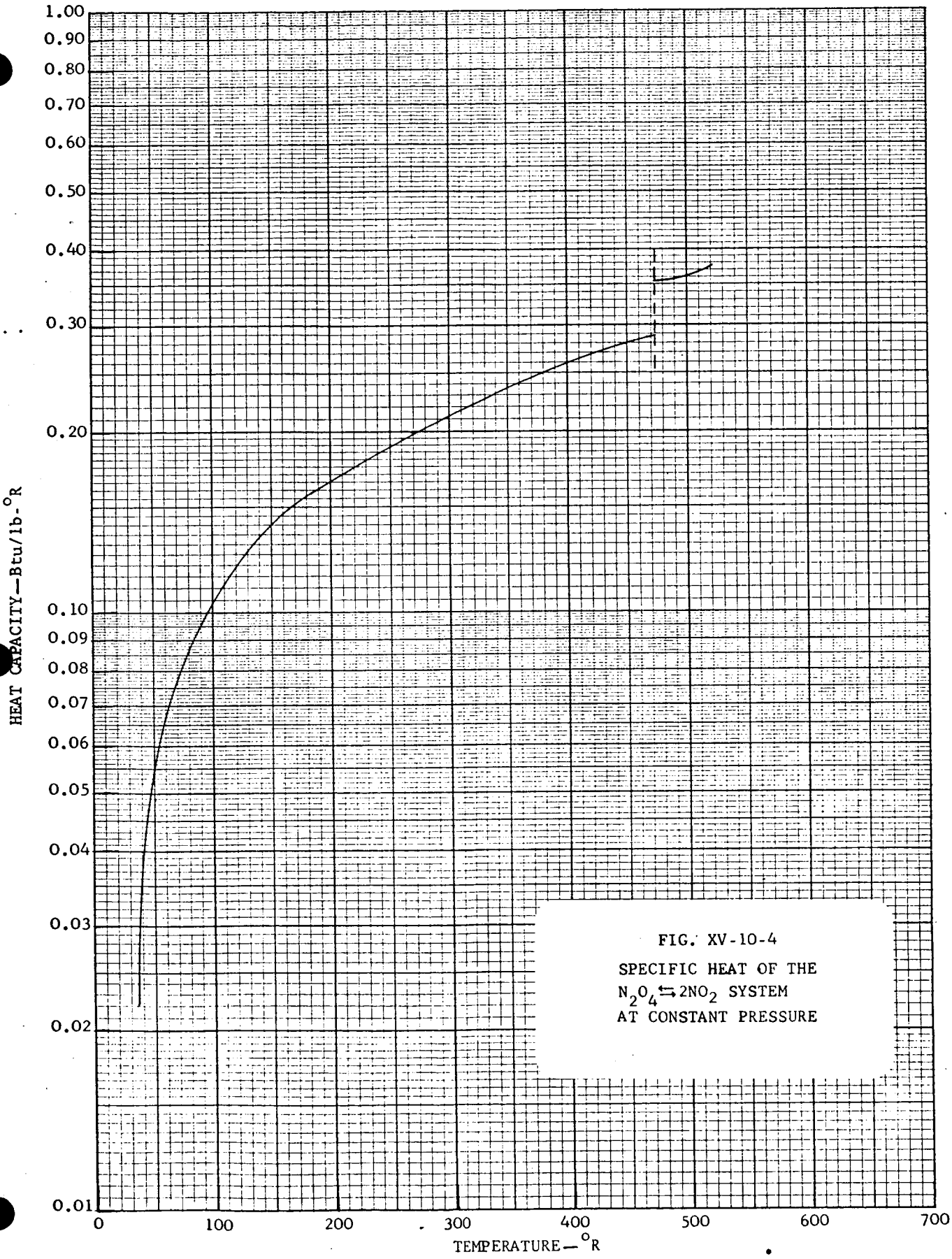

FIG. XV-10-4

SPECIFIC HEAT OF THE $N_2O_4 \leftrightarrows 2NO_2$ SYSTEM AT CONSTANT PRESSURE

XV-10 NITROGEN (IV) OXIDE REFERENCES

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2. Beamer, H. H., and Sage, B. H., *Ind. Eng. Chem.*, **44**, 185 (1952).
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Table XV-11-1

GENERAL PROPERTIES OF UDMH

(Unsymmetrical Dimethyl Hydrazine)

PROPERTY	TEMPERATURE							REF
	°C	°K	°F		psia	atm	mm of Hg	
Melting Point	-57.21	215.94	-70.98	388.69				1
Boiling Point	63.4	336.6	146.2	605.9				1
Triple Point	-57.21	215.94	-70.98	388.69				1
Critical Temp.	249	522	480	940				1
Critical Press.					882	60	45,600	1
Mol. Wt. 60.10								
Heat of Vaporization 139.3 cal/g or 250.6 Btu/lb at 25°C								1
Heat of Fusion 40.06 cal/g or 72.11 Btu/lb								1

Table XV-11-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR UDMH

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.36534	1.41070	1037.66	20.0651
$mole/cm^3$	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0218704	0.0225970	16.6215	0.321408
$lb/mole/ft^3$	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.758520	0.783723	576.475	11.1473
$mole/cm^3$	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0121502	0.0125539	9.23416	0.178559
$lb/mole/ft^3$	0.730228	0.754489	554.973	10.7314

Table XV-11-2

VAPOR PRESSURE OF UDMH
(Ref. 1)

TEMPERATURE		PRESSURE	
°K	°R	psia	atm
220	396	0.0136	0.0009
230	414	0.0348	0.0024
240	432	0.081	0.0055
250	450	0.175	0.0119
260	468	0.351	0.0239
270	486	0.663	0.0451
280	504	1.19	0.0808
290	522	2.02	0.138
300	540	3.31	0.225
310	558	5.19	0.353
320	576	7.88	0.536
330	594	11.58	0.788
340	612	16.53	1.125
350	630	23.01	1.566
360	648	31.25	2.126
370	666	41.56	2.828
380	684	54.16	3.686

(See Figure XV-11-1)

Table XV-11-3

DENSITY OF LIQUID UDMH (Ref. 2)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft^3	°K	°R	lb/ft^3
212.5	382.5	54.64	271.4	488.5	50.95
218.2	392.8	54.22	273.2	491.8	50.89
222.9	401.2	53.96	273.2	491.8	50.72
228.2	410.8	53.56	282.0	507.6	50.26
233.9	421.0	53.32	283.2	509.8	50.06
238.2	428.8	52.97	287.0	516.6	49.75
242.5	436.5	52.76	287.3	517.1	49.89
248.2	446.8	52.30	298.2	536.8	49.08
249.4	448.9	52.45	323.2	581.8	48.39
252.7	454.9	52.08	328.2	590.8	47.58
258.2	464.8	51.69	333.2	599.8	46.96
262.1	471.8	51.51			
268.2	482.8	51.05			

(See Figure XV-11-2)

Table XV-11 -4

VISCOSITY OF UDMH (Ref. 2)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	R	centipoises
218	393	5.114
228	411	3.078
238	429	2.026
248	447	1.462
258	465	1.108
268	483	0.878
273	492	0.783
283	510	0.645
287	517	0.601
298	537	0.509
311	560	0.413
317	571	0.382
322	580	0.356
327	589	0.336
333	600	0.316

(See Figure XV-11-3)

Table XV-11-5

HEAT CAPACITY OF UDMH (Ref. 1)

TEMPERATURE		C_p	TEMPERATURE		C_p
°K	°R	Btu/lb -°R	°K	°R	Btu/lb -°R
13	23.4	0.0108	145	261	0.2706
14	25.2	0.0134	150	270	0.2775
15	27.0	0.0158	155	279	0.2846
16	28.9	0.0184	160	288	0.2915
17	30.6	0.0213	165	297	0.2984
18	32.4	0.0243	170	306	0.3052
19	34.2	0.0273	175	315	0.3118
20	36.0	0.0303	180	324	0.3182
21	37.8	0.0333	185	333	0.3254
22	39.6	0.0363	190	342	0.3324
23	41.4	0.0393	195	351	0.3399
24	43.2	0.0423	200	360	0.3475
25	45.0	0.0453	205	369	0.3555
30	54.0	0.0623	210	378	0.3640
35	63.0	0.0784	215	387	0.3722
40	72.0	0.0925	215.95	388.7	0.3738 crystal fusion
45	81.0	0.1056			
50	90.0	0.1180			
55	99.0	0.1292	215.95	388.7	0.6034 liquid
60	108.0	0.1385	220	396	0.6059
65	117.0	0.1483	225	405	0.6100
70	126.0	0.1578	230	414	0.6135
75	135.0	0.1666	235	423	0.6172
80	144.0	0.1754	240	432	0.6202
85	153.0	0.1840	245	441	0.6232
90	162.0	0.1915	250	450	0.6258
95	171.0	0.1987	255	459	0.6285
100	180.0	0.2061	260	468	0.6325
105	189.0	0.2133	265	477	0.6337
110	198.0	0.2206	270	486	0.6363
115	207.0	0.2277	275	495	0.6391
120	216.0	0.2350	280	504	0.6423
125	225.0	0.2423	285	513	0.6455
130	234.0	0.2495	290	522	0.6483
135	243.0	0.2566	295	531	0.6510
140	252.0	0.2636	298.16	536.6	0.6526

(See Figure XV-11-4)

Table XV-11-6

THERMAL CONDUCTIVITY OF UDMH
(Ref. 2,3)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
227.8	410	0.1094
255.6	460	0.1080
283.3	510	0.1053
311.1	560	0.1024
338.9	610	0.0990
366.7	660	0.0960
394.4	710	0.0930

(See Figure XV-11-5)

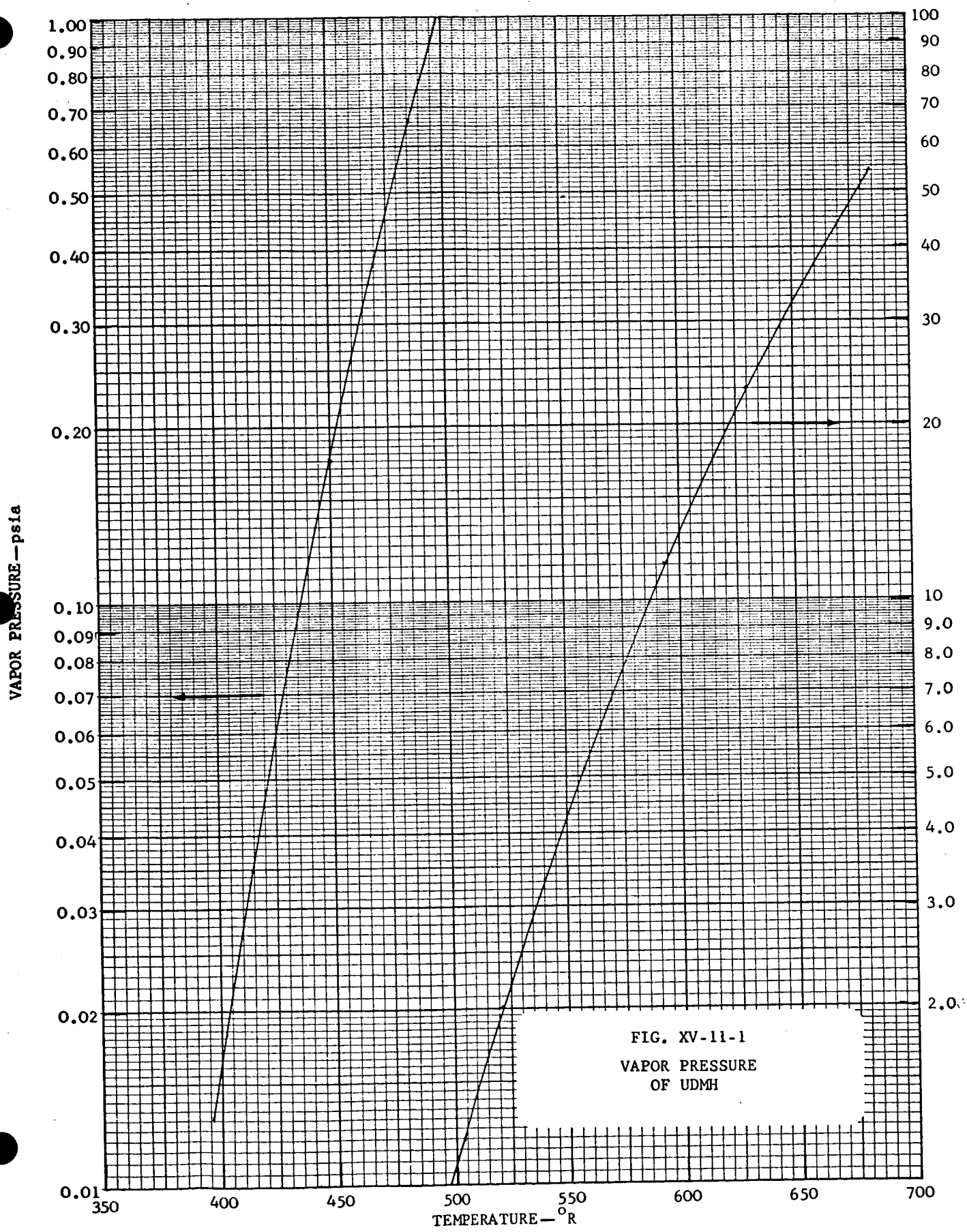


FIG. XV-11-1

VAPOR PRESSURE
OF UDMH

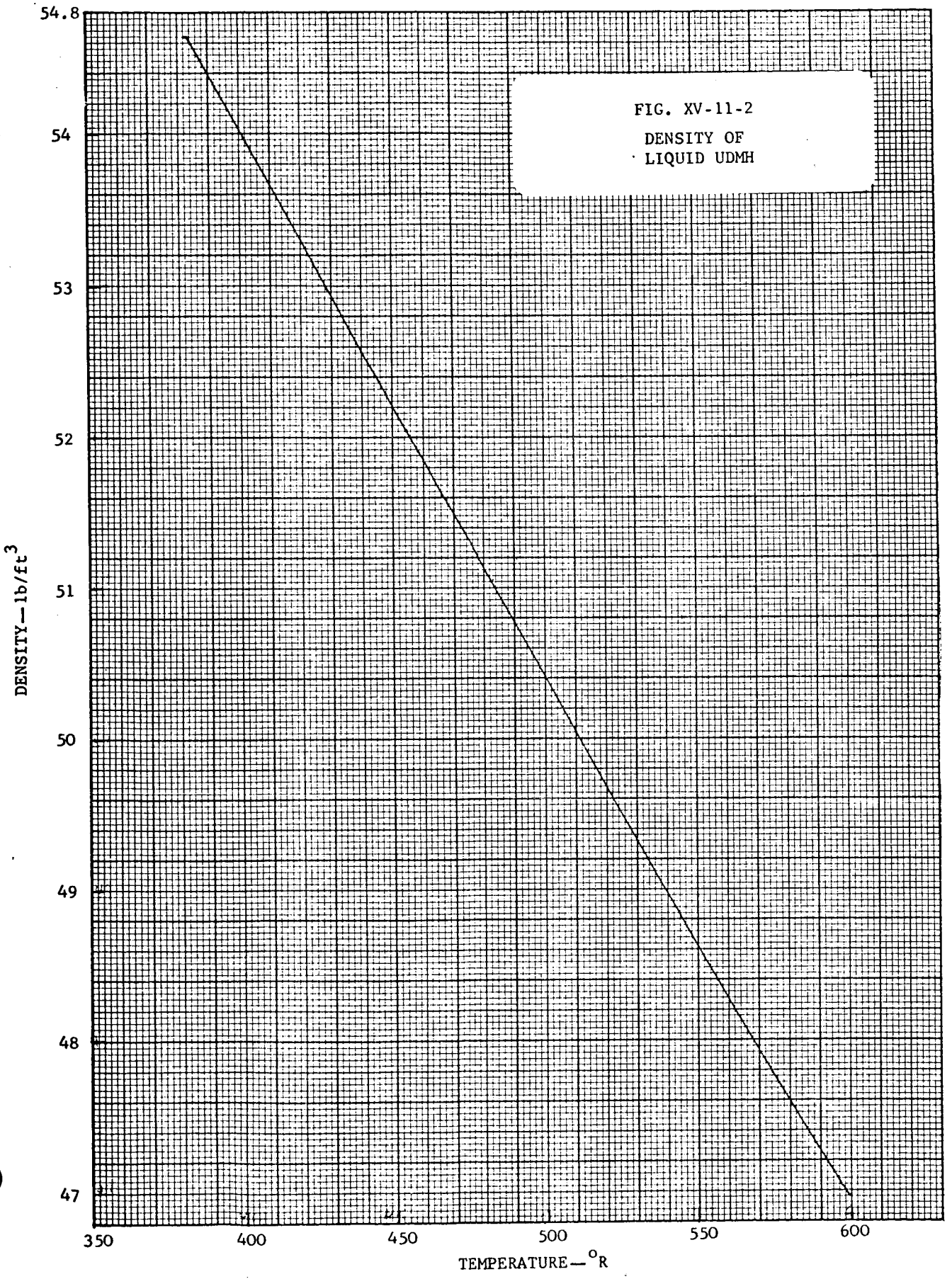


FIG. XV-11-2

DENSITY OF LIQUID UDMH

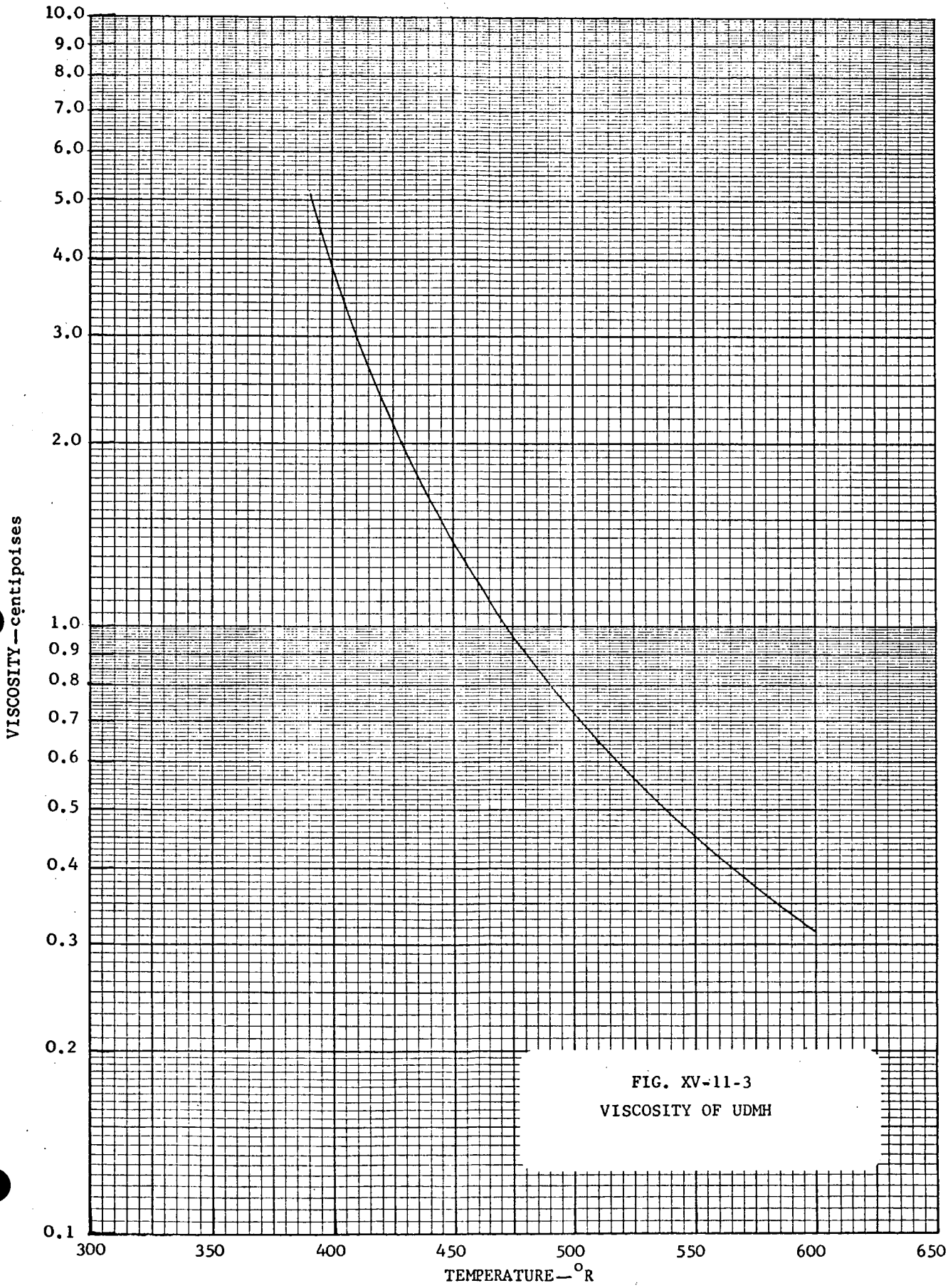


FIG. XV-11-3
VISCOSITY OF UDMH

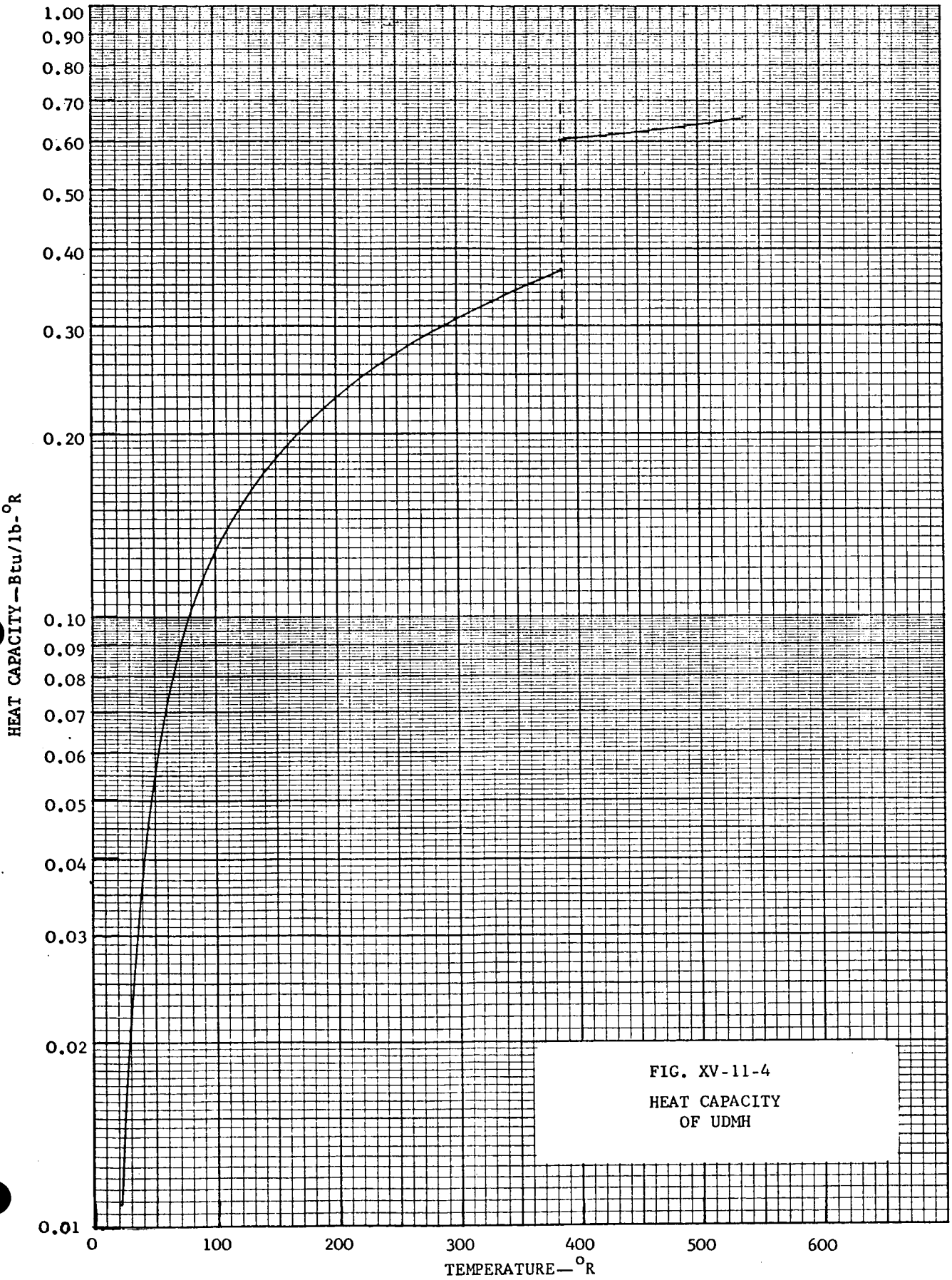


FIG. XV-11-4

HEAT CAPACITY
OF UDMH

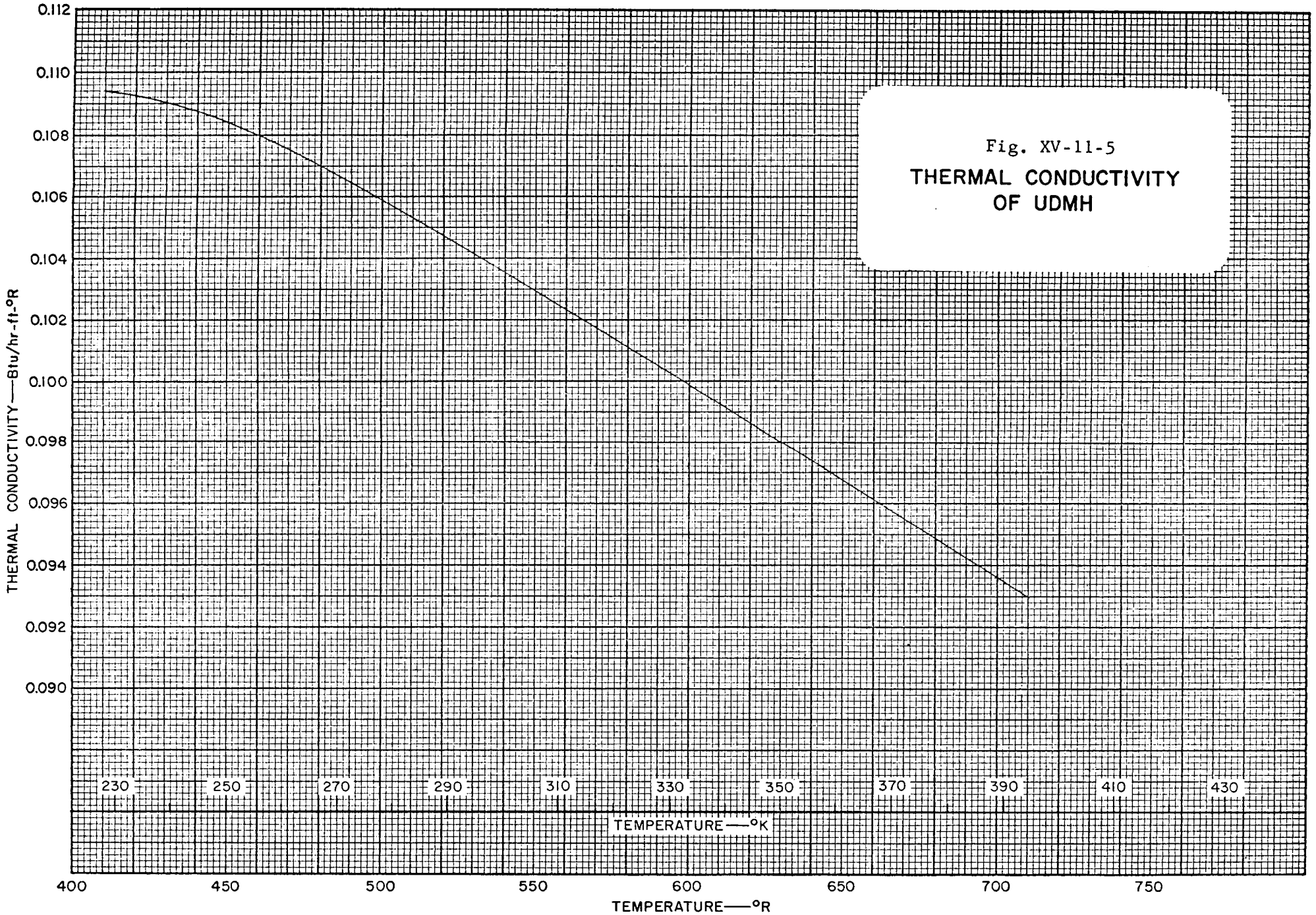


Fig. XV-11-5

THERMAL CONDUCTIVITY OF UDMH

XV-11 UDMH REFERENCES

1. Aston, J. G., Wood, J. L., and Zolki, T. P., *J. Am. Chem. Soc.*, **75**, 6202 (1953).
2. Petrozzi, P. J., and Dean, L. E., Aerojet-General Corp., *Report No. LRP-178*, 13 July 1960.
3. Weber, H. F., *Wiedeman's Ann.*, **10**, 103 (1880).

Table XV-12-1

PHYSICAL CONSTANTS

OF

WATER

		REF.
Molecular Weight	18.016	8
Boiling Point @ 1 atm	$212^{o}F$	8
Freezing Point @ 1 atm	$32^{o}F$	8
Specific Volume @ $70^{o}F$	0.01606 cu ft/lb	12
Vapor Pressure @ $68^{o}F$	0.3391 psia	10
Specific Gravity, (Air = 1) @ $39.1^{o}F$	1.00	9
Density		
Liquid @ $39.1^{o}F$	62.4266 lb/cu ft	9
Gas @ $300^{o}F$	0.03275 lb/cu ft	12
Critical Temperature	$705.4^{o}F$	8
Critical Pressure	3206 psia	8
Critical Density	20.35 lb/cu ft	10
Latent Heat of Vaporization @ b.p.	970.3 Btu/lb	8
Latent Heat of Fusion @ m.p.	143.4 Btu/lb	11
Specific Heat of Gas		
c_p @ $212^{o}F$	0.4836 Btu/lb-^{o}F	8
c_v @ $212^{o}F$	0.3652 Btu/lb-^{o}F	8
Specific Heat Ratio, c_p/c_v	1.324	8
Thermal Conductivity @ $50^{o}F$	0.320 Btu/hr-ft-^{o}R	8
Viscosity		
Liquid @ $68.4^{o}F$	6.72×10^{-4} lb/ft-sec	8
Gas		
Solubility in Water		
Surface Tension @ $77^{o}F$	4.93×10^{-3} lb/ft	8

Table XV-12-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR WATER
(See also Conversion Tables, Section 1)

TEMPERATURE IN ^{o}K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	4.55466	4.70660	3461.54	66.9353
$mole/cm^3$	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3616	1.20587
lb/ft^3	0.0729579	0.753821	55.4480	1.07219
$lb/mole/ft^3$	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN ^{o}R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.53037	2.61444	1923.08	37.1863
$mole/cm^3$	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455853	0.0471005	34.6452	0.669928
lb/ft^3	0.0405322	0.0418789	30.8044	0.505661
$lb/mole/ft^3$	0.730228	0.754489	554.973	10.7314

Table XV-12-2

VAPOR PRESSURE OF ICE
(Ref. 4)

TEMPERATURE		VAPOR PRESSURE
^{o}K	^{o}R	atm
154	277.2	0.0000000001
155	279.0	0.0000000003
160	288.0	0.0000000008
170	306.0	0.000000007
180	324.0	0.00000005
190	342.0	0.00000032
200	360.0	0.00000158
210	378.0	0.00000687
220	396.0	0.0000262
230	414.0	0.0000883
240	432.0	0.0002696
250	450.0	0.000751
260	468.0	0.001933
270	486.0	0.004633
273	491.4	0.005946

(See Figure XV-12-1)

Table XV-12-3

VAPOR PRESSURE OF WATER (Ref. 4)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	atm	°K	°R	atm
274	493.2	0.006406	420	756	4.3127
275	495	0.006883	440	792	7.2372
280	504	0.009774	460	828	11.554
290	522	0.018917	480	864	17.670
300	540	0.034844	500	900	26.050
320	576	0.10388			
340	612	0.26785			
360	648	0.61290			
380	684	1.2702			
400	720	2.4232			

(See Figure XV-12-2)

Table XV-12-4

DENSITY OF WATER (Ref. 12)

DENSITY-lb/ft^3					
PRESSURE psia \ TEMP. °R	492	560	660	760	860
14.7	62.42	62.00	60.13	0.03275	0.02884
200	62.46	62.03	60.16	57.35	0.4235
400	62.50	62.07	60.20	57.40	53.68
600	62.55	62.11	60.24	57.45	53.78
1000	62.64	62.19	60.31	57.54	53.90
1500	62.74	62.28	60.41	57.65	54.06
2000	62.85	62.37	60.52	57.77	54.22
3000	63.06	62.56	60.70	58.00	54.53
4000	63.26	62.73	60.89	58.23	54.83
6000	63.67	63.08	61.25	58.67	55.40

(See Figure XV-12-3)

Table XV-12-5

DENSITY OF STEAM (Ref. 12)

DENSITY-lb/ft^3									
PRESSURE psia \ TEMP. °R	960	1060	1160	1260	1360	1460	1660	1860	2060
14.696	.0258	.0233	.0213	.0196	.0182	.0169	.0149	.0133	.0120
50	.0884	.0798	.0728	.0669	.0619	.0576	.0564	.0452	.0408
100	.1789	.1608	.1463	.1343	.1242	.1155	.1014	.0904	.0816
200	.3668	.3268	.2959	.2708	.2499	.2321	.2034	.1811	.1633
400	.7782	.6771	.6058	.5506	.5059	.4686	.4090	.3635	.3273
600	1.2583	1.0568	.9318	.8404	.7685	.7094	.6170	.5471	.4919
1000		1.9455	1.6437	1.4540	1.3151	1.2057	1.0400	.9180	.8233
1500		3.5240	2.6889	2.2978	2.0437	1.8553	1.5828	1.3891	1.2413
2000			4.0177	3.2531	2.8313	2.5413	2.1423	1.8685	1.6636
3000			10.1626	5.6818	4.6318	4.0388	3.3135	2.8531	2.5214
4000			34.8432	9.5057	6.8400	5.7372	4.5620	3.8745	3.3979
5500			38.1680	21.5983	11.3636	8.7489	6.5963	5.4795	4.7483

Table XV-12-6

VISCOSITY OF WATER (Ref. 3)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
^{o}K	^{o}R	centipoises	^{o}K	^{o}R	centipoises
273.15	491.67	1.7291	373.15	671.67	0.2838
283.15	509.67	1.3077	383.15	689.67	0.256
293.15	527.67	1.0050	393.15	707.67	0.232
303.15	545.67	0.8007	403.15	725.67	0.212
313.15	563.67	0.6560	413.15	743.67	0.196
323.15	581.67	0.5494	423.15	761.67	0.184
333.15	599.67	0.4688	433.15	779.67	0.174
343.15	617.67	0.4061			
353.15	635.67	0.3565			
363.15	653.67	0.3165			

(See Figure XV-12-4)

Table XV-12-7

VISCOSITY OF STEAM
AT ONE ATMOSPHERE
(Ref. 4)

TEMPERATURE		ABSOLUTE VISCOSITY
^{o}K	^{o}R	centipoises
280	504	0.00909
300	540	0.00981
320	576	0.01053
340	612	0.01125
360	648	0.01198
380	684	0.01270
400	720	0.01342
420	756	0.01414
440	792	0.01486
460	828	0.01559
480	864	0.01631
500	900	0.01703

(see Figure XV-12-5)

Table XV-12-8

HEAT CAPACITY OF ICE (Ref. 2)

TEMPERATURE		HEAT CAPACITY, C_p	TEMPERATURE		HEAT CAPACITY, C_p
°K	°R	Btu/lb-°R	°K	°R	Btu/lb-°R
20	36	0.0272	160	288	0.3081
30	54	0.0546	170	306	0.3244
40	72	0.0814	180	324	0.3409
50	90	0.1052	190	342	0.3574
60	108	0.1279	200	360	0.3743
70	126	0.1499	210	378	0.3926
80	144	0.1707	220	396	0.4103
90	162	0.1914	230	414	0.4275
100	180	0.2107	240	432	0.4418
110	198	0.2292	250	450	0.4622
120	216	0.2461	260	468	0.4797
130	234	0.2624	270	486	0.4974
140	252	0.2772	273	491	0.504
150	270	0.2922			

(See Figure XV-12-6)

Table XV-12-9

HEAT CAPACITY OF WATER (Ref. 1, 2)

TEMPERATURE		HEAT CAPACITY, C_p Btu/lb-°R	
°K	°R	1 atm	48.4 atm
273.15	491.67	1.0071	1.004
293.15	527.67	0.9985	0.9959
313.15	563.67	0.9975	0.9940
333.15	599.67	0.9989	0.9950
353.15	635.67	1.000	0.9990
373.15	671.67	1.002	1.004
393.15	707.67	1.014	1.011
413.15	743.67	1.0206	1.019
433.15	779.67	1.0275	1.033
453.15	815.67	1.0357	1.050
473.15	851.67	1.0439	1.071

(See Figure XV-12-7)

Table XV-12-10

HEAT CAPACITY OF STEAM
(Ref. 4)

TEMPERATURE		HEAT CAPACITY, C_P Btu/lb-°R	
°K	°R	1 atm	10 atm
380	684	0.492	
390	702	0.485	
400	720	0.480	
420	756	0.475	
440	792	0.473	
460	828	0.472	0.619
480	864	0.472	0.577
500	900	0.473	0.550

(See Figure XV-12-8)

Table XV-12-11

THERMAL CONDUCTIVITY OF WATER
(Ref. 2)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
273.15	491.67	0.320
283.15	509.67	0.333
293.15	527.67	0.346
303.15	545.67	0.356
313.15	563.67	0.364
323.15	581.67	0.372
333.15	599.67	0.378
343.15	617.67	0.385
353.15	635.67	0.388
363.15	653.67	0.391
373.15	671.67	0.393
393.15	707.67	0.397
413.15	743.67	0.397
433.15	779.67	0.395
453.15	815.67	0.391
473.15	851.67	0.385

(See Figure XV-12-10)

Table XV-12-12

THERMAL CONDUCTIVITY OF STEAM (Ref. 4)

		THERMAL CONDUCTIVITY - Btu/ft-hr-°R				
TEMP. °K	PRESS. atm °R	1	10	40	70	100
380	684	.02166				
380	702	.02230				
400	720	.02297				
410	738	.02365				
420	756	.02432				
430	774	.02500				
440	792	.02569				
450	810	.02639	.02897			
460	828	.02709	.02940			
470	846	.02780	.02986			
480	864	.02852	.03037			
490	882	.02923	.03090			
500	900	.02995	.03147			
510	918		.03207			
520	936		.03269			
530	954		.03331			
540	972		.03392			
550	990		.03454	.03979	.05043	
560	1008		.03521	.03987	.04889	
570	1026		.03590	.04005	.04777	
580	1044		.03657	.04031	.04697	
590	1062		.03724	.04063	.04642	.05628
600	1080		.03791	.04099	.04607	.05443
610	1098		.03861	.04140	.04592	.05303
620	1116		.03931	.04187	.04584	.05198
630	1134		.04001	.04235	.04589	.05124
640	1152		.04073	.04287	.04605	.05071
650	1170		.04143	.04341	.04627	.05037
660	1188		.04215	.04402	.04656	.05019
670	1206		.04287	.04460	.04690	.05013
680	1224		.04360	.04521	.04729	.05018
690	1242		.04431	.04579	.04773	.05032
700	1260		.04502	.04640	.04819	.05053
710	1278		.04577	.04705	.04868	.05081
720	1296		.04649	.04771	.04920	.05113
730	1314		.04724	.04836	.04974	.05149
740	1332		.04796	.04901	.05030	.05191
750	1350		.04869	.04967	.05088	.05236

Table XV-12-13

HEAT OF VAPORIZATION OF WATER (Ref. 12)

PRESSURE	TEMPERATURE		LATENT HEAT
psia	°F	°R	Btu/lb
1	101.74	561.32	1036.3
5	162.24	621.82	1001.0
10	193.21	652.79	982.1
14.696	212.00	671.58	970.3
20	227.96	687.54	960.1
30	250.33	709.91	945.3
40	267.25	726.83	933.7
50	281.01	740.59	924.0
60	292.71	752.29	915.5
70	302.92	762.50	907.9
80	312.03	771.61	901.1
90	320.27	781.65	894.7
100	327.81	787.39	888.8
200	381.79	841.37	843.0
300	417.33	876.91	809.0
400	444.59	904.17	780.5
500	467.01	926.59	755.0
600	486.21	945.79	731.6
700	503.10	962.68	709.7
800	518.23	977.81	688.9
900	531.98	991.56	668.8
1000	544.61	1004.19	649.4
1200	567.22	1026.80	611.7
1400	587.10	1046.68	574.7
1600	604.90	1064.48	538.0
1800	621.03	1080.61	501.1
2000	635.82	1095.40	463.4
2200	649.46	1109.04	424.4
2400	662.12	1121.70	382.7
2600	673.94	1133.52	337.2
2800	684.99	1144.57	284.7
3000	695.36	1154.94	217.8
3200	705.11	1164.69	62.0
3206.2	705.40	1164.98	0

Table XV-12-14

TOTAL ENTHALPY VALUES AND SPECIFIC VOLUMES FOR THE WATER SYSTEM

TEMP.	TOTAL ENTHALPY--Btu/lb			SP.VOL. VAPOR	TEMP.	TOTAL ENTHALPY-- Btu/lb			SP.VOL.VAPOR
°R	Ice	Water	Vapor	ft^3/lb	°R	Ice	Water	Vapor	ft^3/lb
600		381.9	1395.52	122.61	475	121.8	256.8	1340.9	5,498.55
595		375.9	1393.63	138.42	470	119.1	251.8	1338.7	6,996.49
590		371.9	1391.68	156.67	465	116.6	246.7	1336.7	8,950.55
585		366.9	1389.65	177.78	460	114.1	241.7	1334.7	11,258.4
580		361.9	1387.60	202.18	455	111.7	236.7	1332.7	18,616.4
575		356.9	1385.48	230.58	450	109.3	231.7	1330.7	24,271.2
570		351.9	1383.35	263.69	445	107.0	226.7	1328.7	31,623.1
565		346.9	1381.19	302.52	440	104.7	221.8	1326.7	41,473.2
560		341.9	1377.99	347.85	435	102.4	216.7	1324.7	54,908.4
555		336.9	1376.75	401.21	430	100.2	211.7	1322.8	72,816.0
550		331.8	1374.50	464.23	425	98.1	206.6	1320.9	97,481
545		326.8	1372.15	538.62	420	96.0	201.2	1319.0	130,866
540		321.8	1369.98	627.75	415	93.8	194.2	1317.1	171,181
535		316.8	1367.83	733.31	410	91.7	181.1	1315.2	244,227
530		311.8	1365.70	859.69	405	89.6	141.0	1313.4	336,167
525		306.7	1363.51	1012.75	400	87.6		1310.6	466,928
520		301.8	1361.32	1195.41	390	83.5		1305.3	929,255
515		296.7	1359.12	1416.49	380	79.4		1300.	1,915,177
510		291.7	1356.88	1685.27	360	71.4		1290.	9,229,215
505		286.7	1354.67	2017.51	350	67.5		1285.	21,480,455
500		281.6	1352.48	2421.45	330	60.0		1275.	140,705,052
495		276.7	1350.20	2913.04	310	53.0		1267.	12,556,860,000
490	129.2	271.7	1347.90	3591.74					
485	126.7	266.8	1345.55	4433.62					
480	124.2	261.8	1342.9	5498.55					

(See Figure XV-12-12,
Figure XV-12-13)

Table XV-12-15

SURFACE TENSION OF WATER
IN CONTACT WITH AIR
(Ref. 2)

TEMPERATURE		SURFACE TENSION
°K	°R	dynes/cm
273.15	491.67	75.60
283.15	509.67	74.22
293.15	527.67	72.75
303.15	545.67	71.18
313.15	563.67	69.56
323.15	581.67	67.91
333.15	599.67	66.19
343.15	617.67	64.4
353.15	635.67	62.6
363.15	653.67	60.7
373.15	671.67	58.8
383.15	689.67	56.8*
393.15	702.67	54.8*
403.15	725.67	52.8*

* In contact with steam

(See Figure XV-12-14)

Table XV-12-16

LOW FREQUENCY VELOCITY OF SOUND
IN WATER VAPOR (Ref. 13)

TEMPERATURE		VELOCITY
°R	°F	ft/sec
200	-259.7	857.8
250	-209.7	959.0
300	-159.7	1050.4
350	-109.7	1134.5
400	- 59.7	1212.7
450	- 9.7	1285.9
500	40.3	1354.9
550	90.3	1420.2
600	140.3	1482.3
650	190.3	1541.5
700	240.3	1598.0
750	290.3	1652.3
800	340.3	1704.4
850	390.3	1754.7
900	440.3	1803.3

(See Figure XV-12-15)

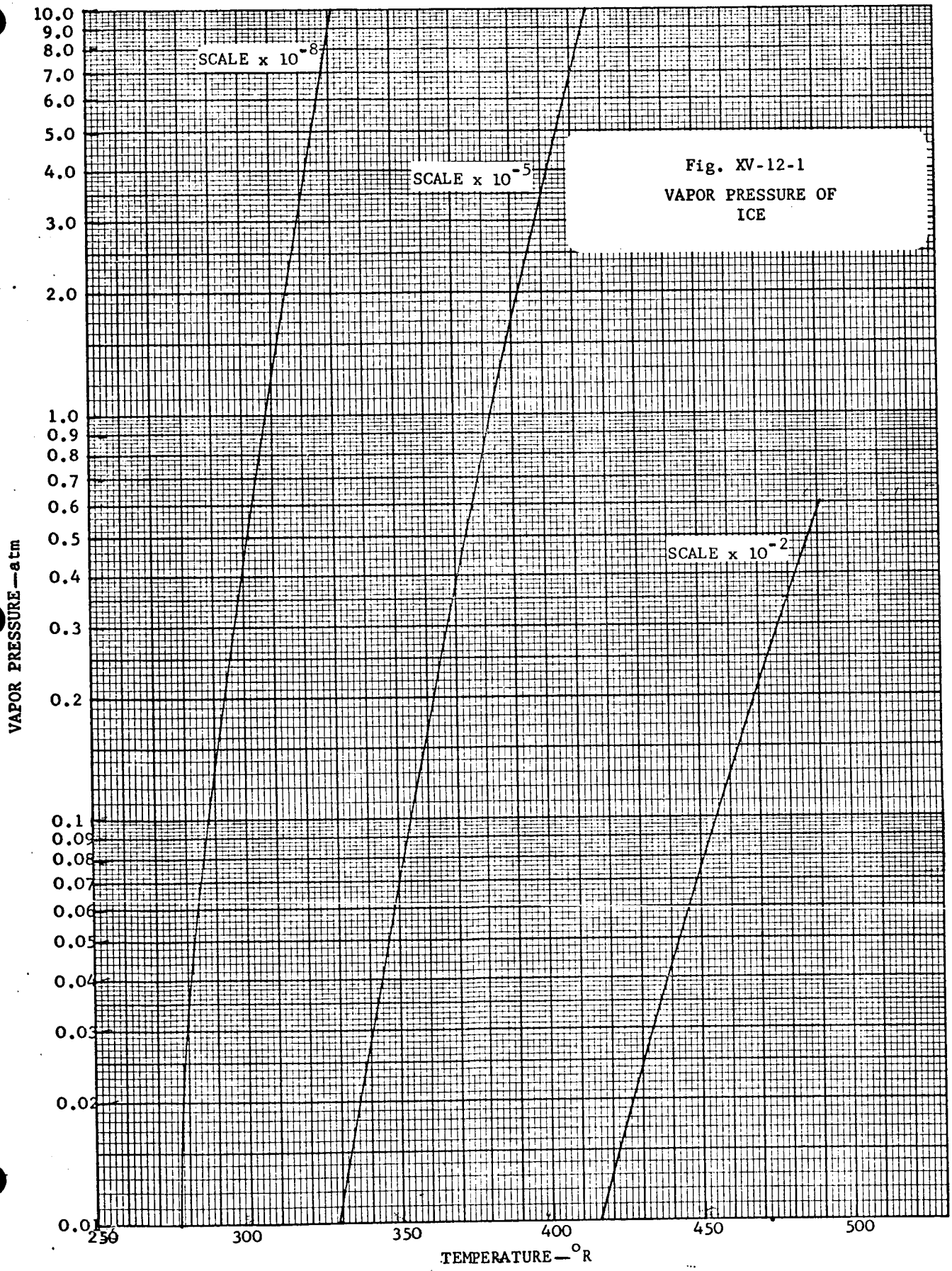


Fig. XV-12-1
VAPOR PRESSURE OF ICE

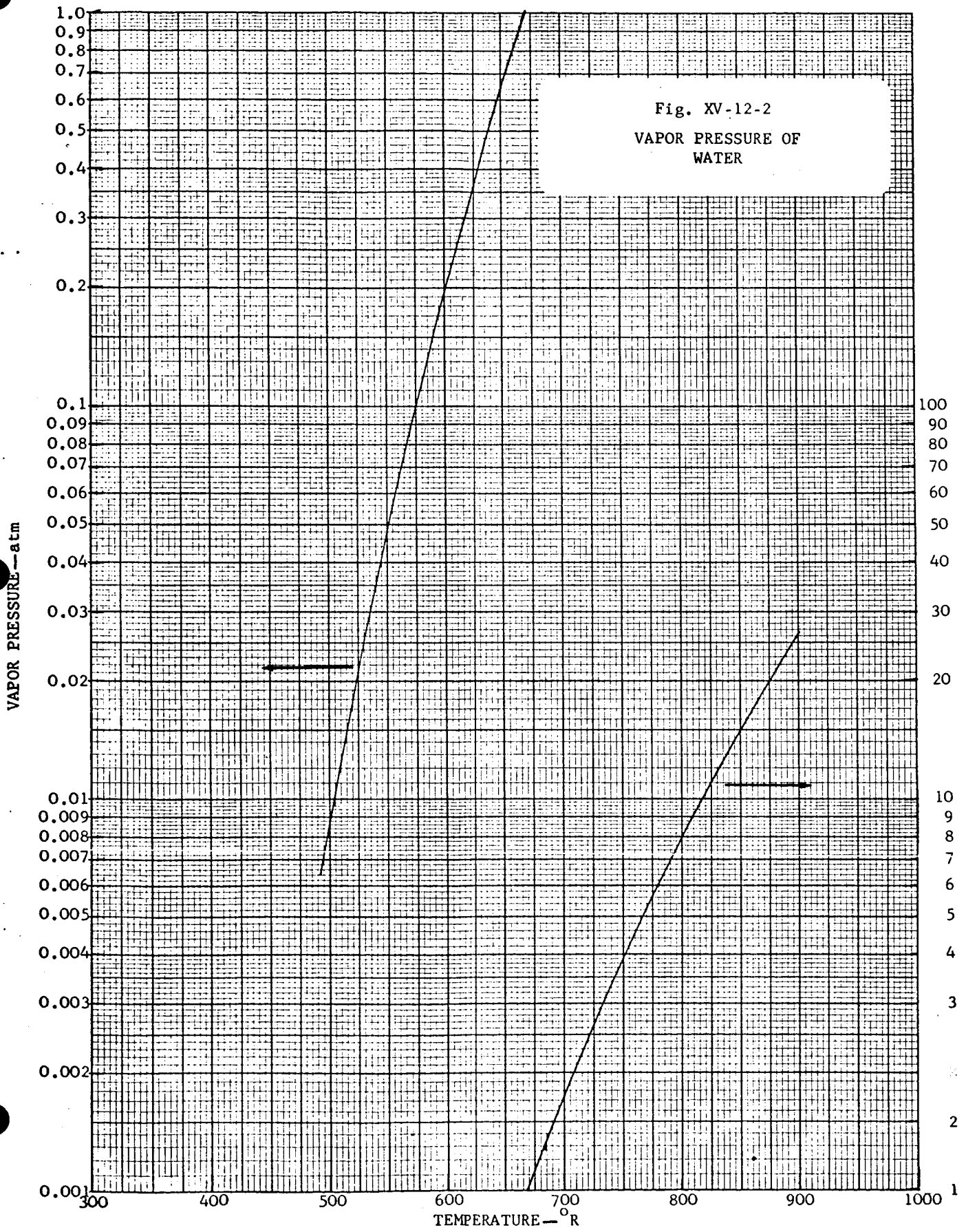
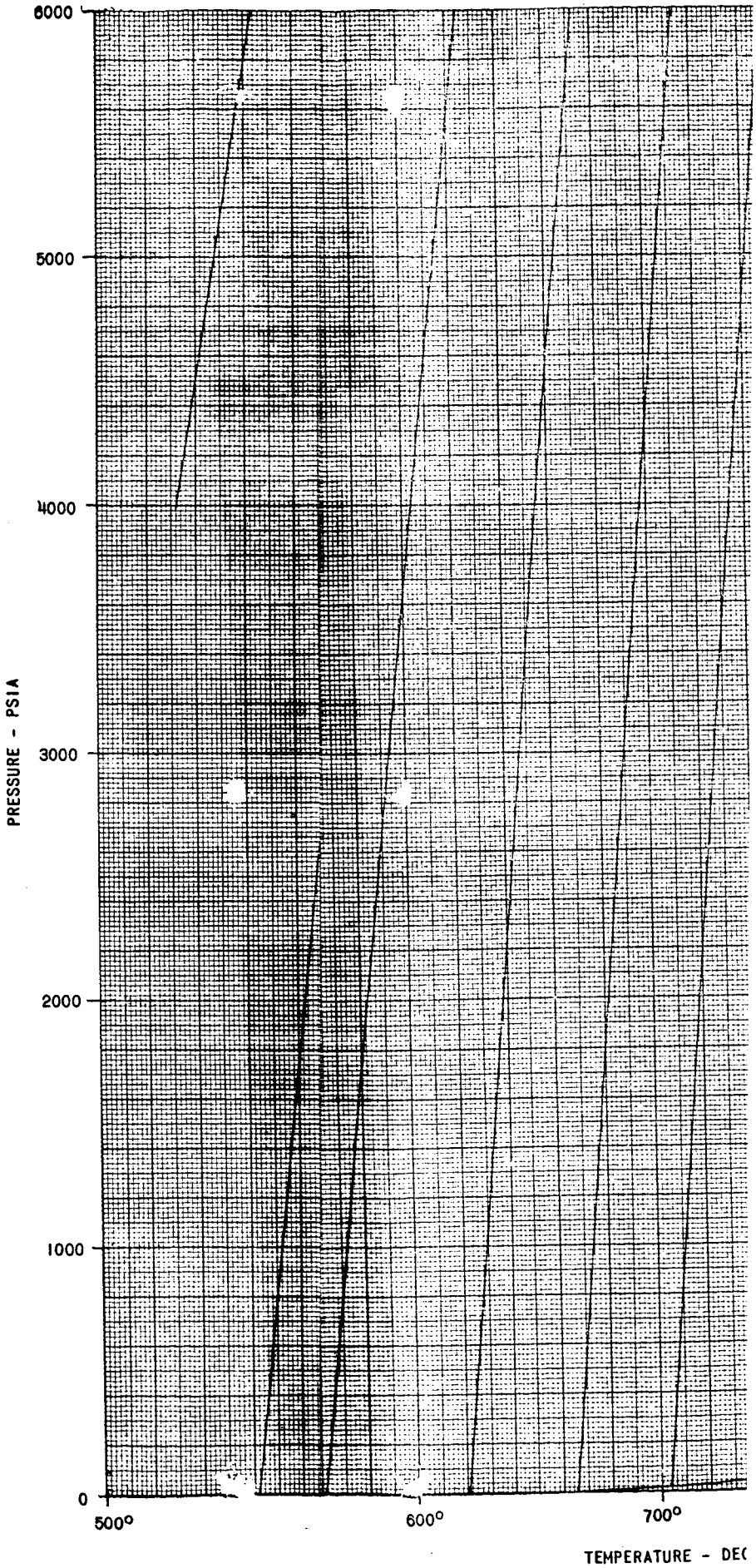


Fig. XV-12-2
VAPOR PRESSURE OF WATER
VAPOR PRESSURE—atm
TEMPERATURE—°R
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
300
400
500
600
700
800
900
1000


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
500°
600°
700°
TEMPERATURE - DE(

XV-12-3

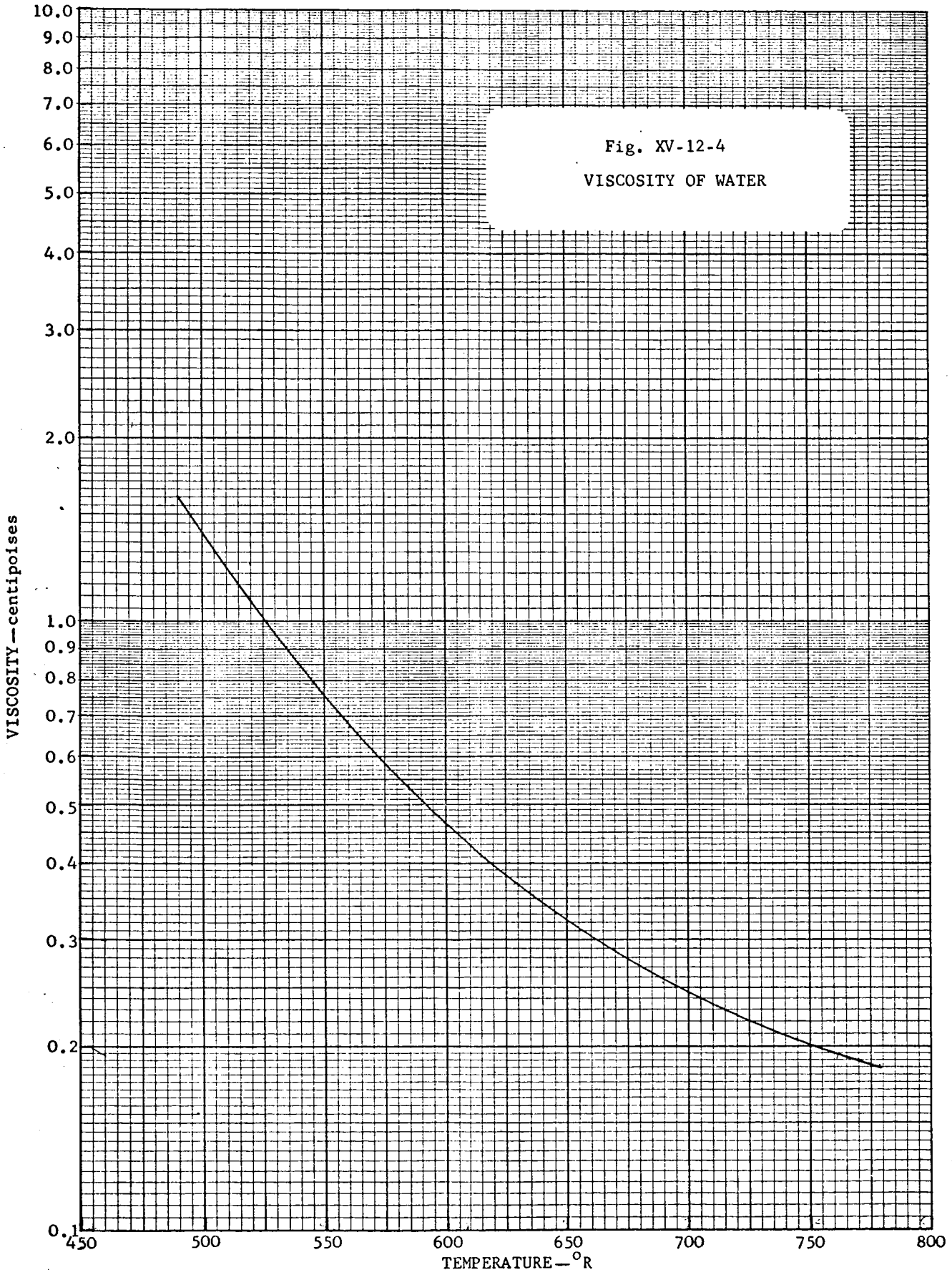


Fig. XV-12-4

VISCOSITY OF WATER

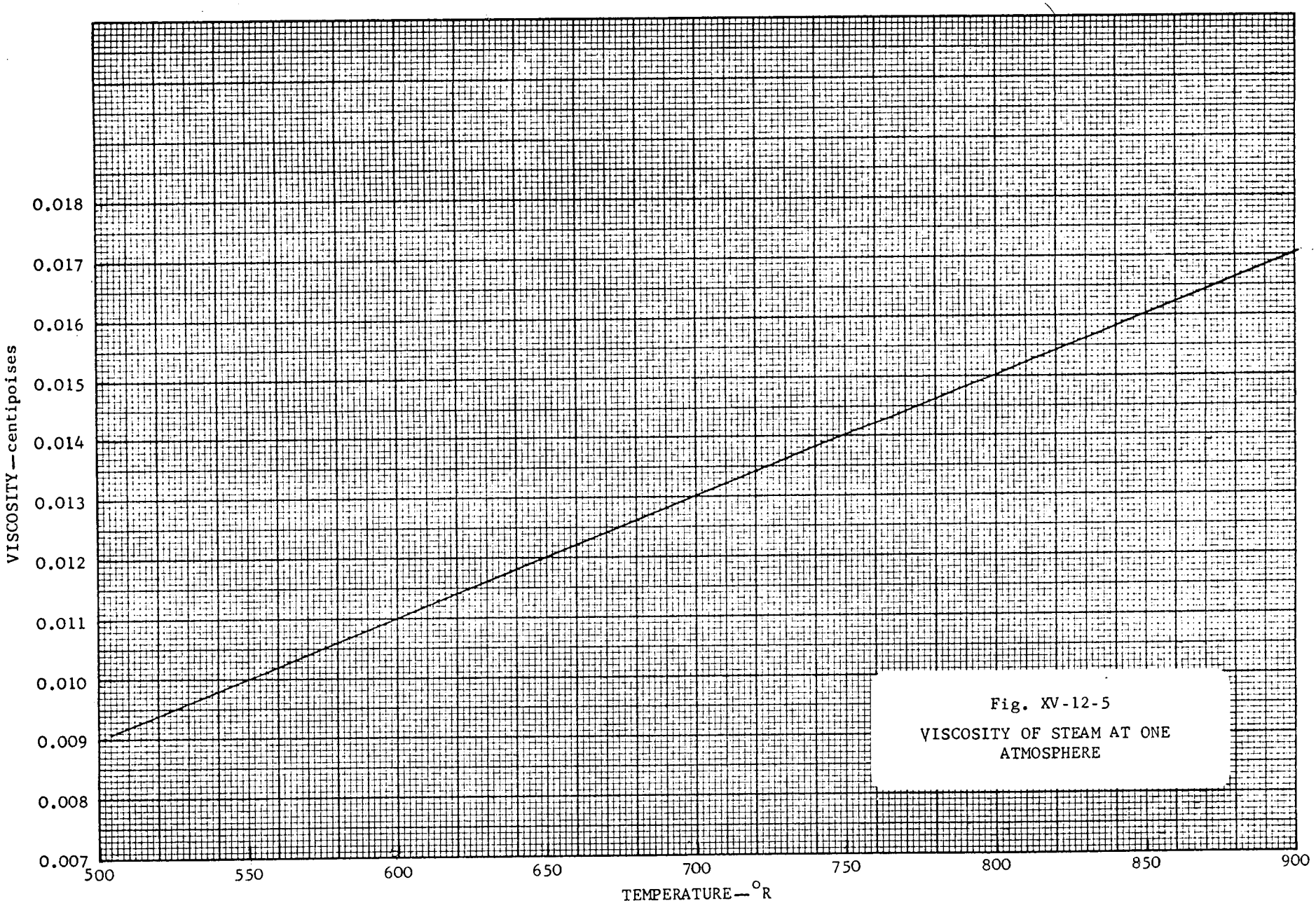


Fig. XV-12-5

VISCOSITY OF STEAM AT ONE ATMOSPHERE

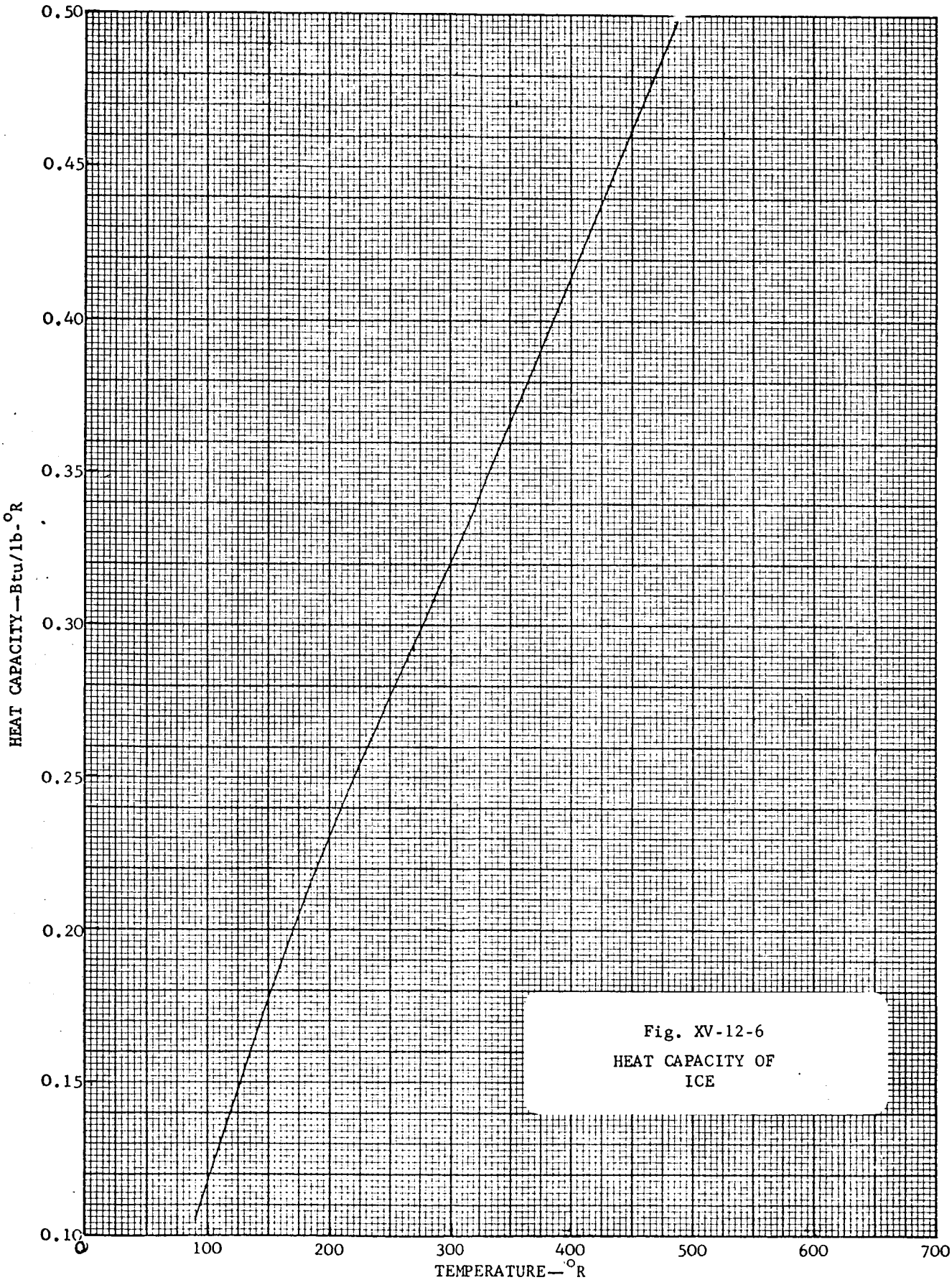


Fig. XV-12-6

HEAT CAPACITY OF ICE

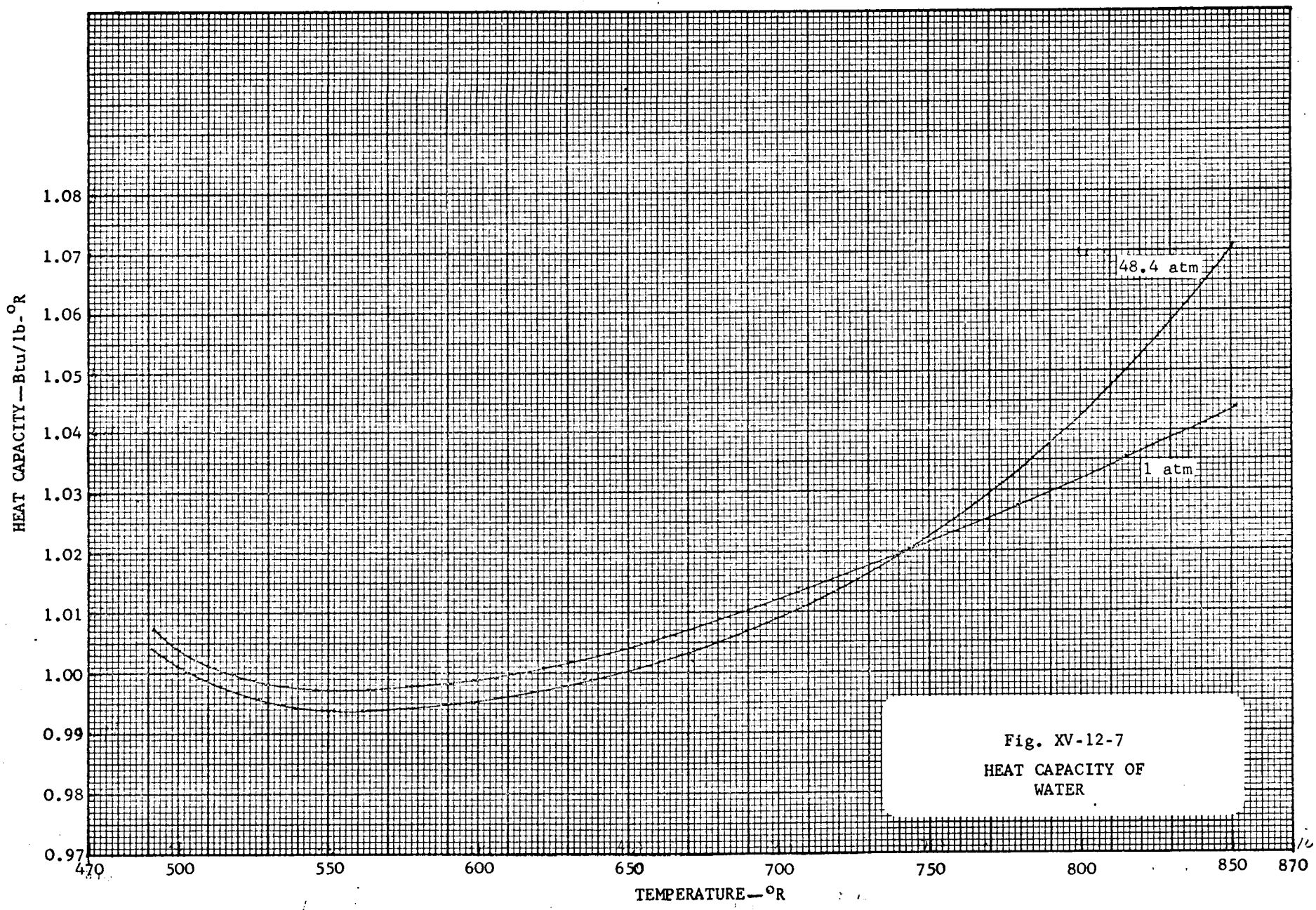


Fig. XV-12-7

HEAT CAPACITY OF WATER

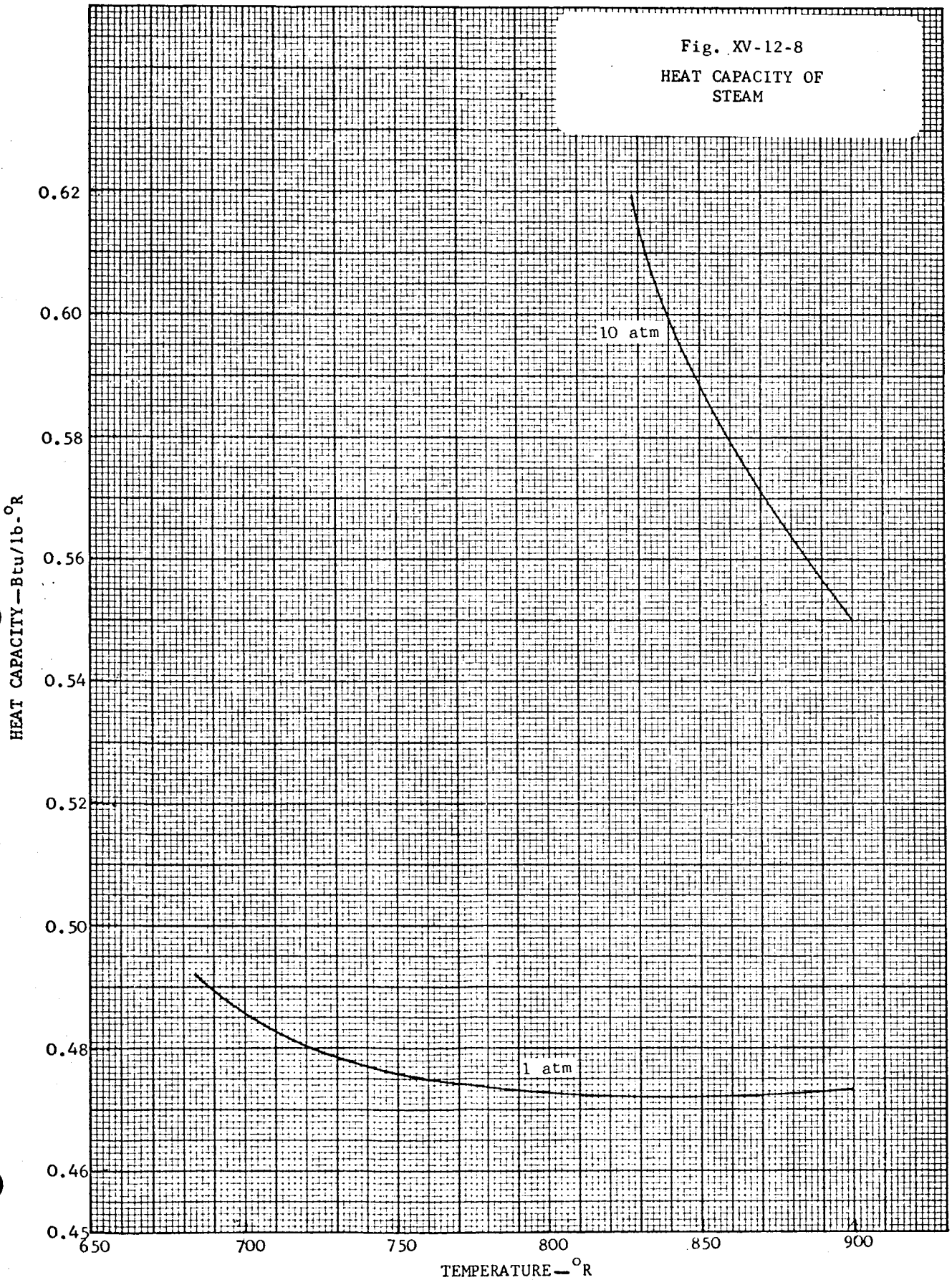


Fig. XV-12-8

HEAT CAPACITY OF STEAM

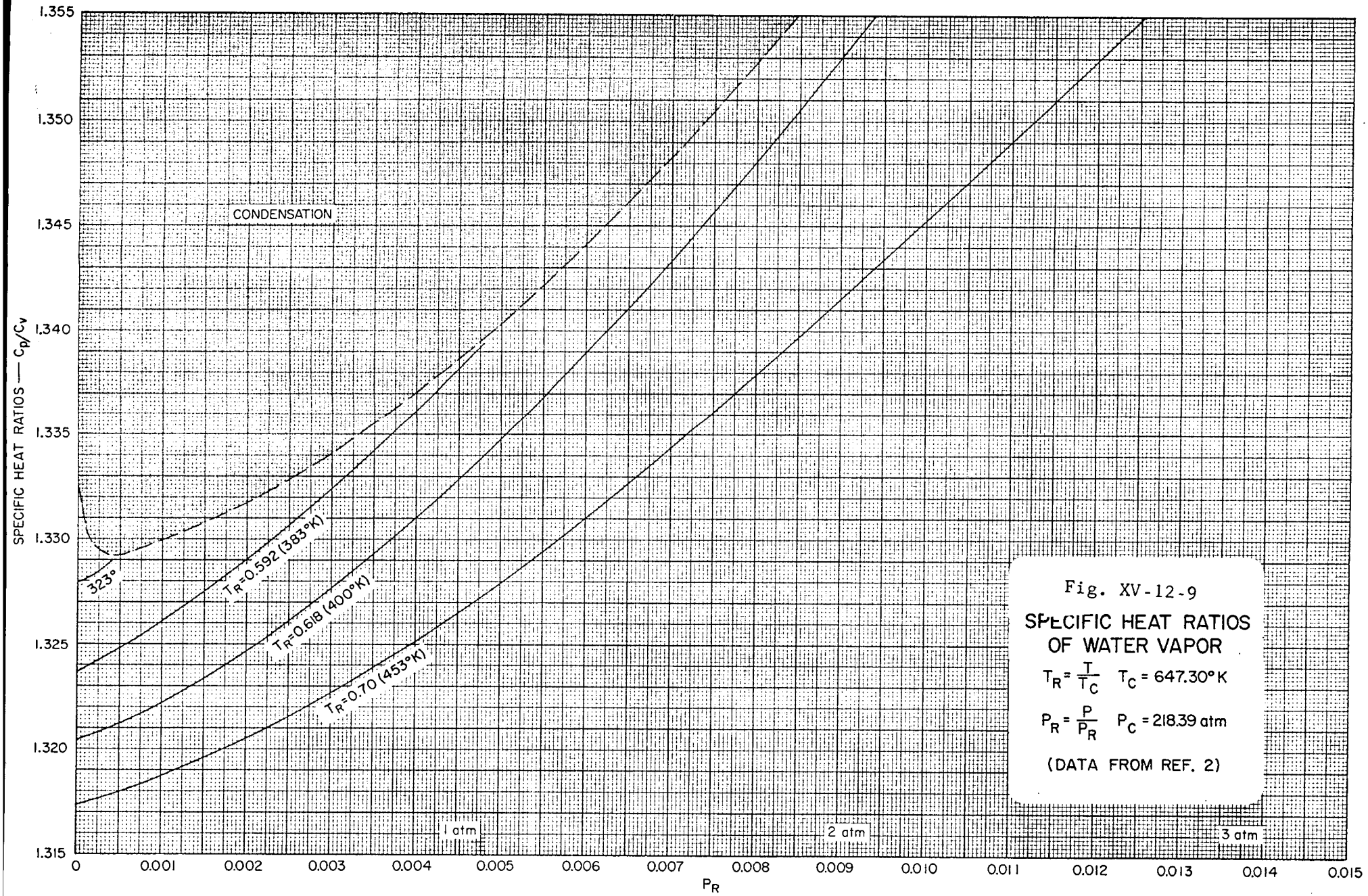


Fig. XV-12-9

SPECIFIC HEAT RATIOS OF WATER VAPOR

$T_R = \frac{T}{T_C}$ T_C = 647.30° K

$P_R = \frac{P}{P_R}$ P_C = 218.39 atm

(DATA FROM REF. 2)

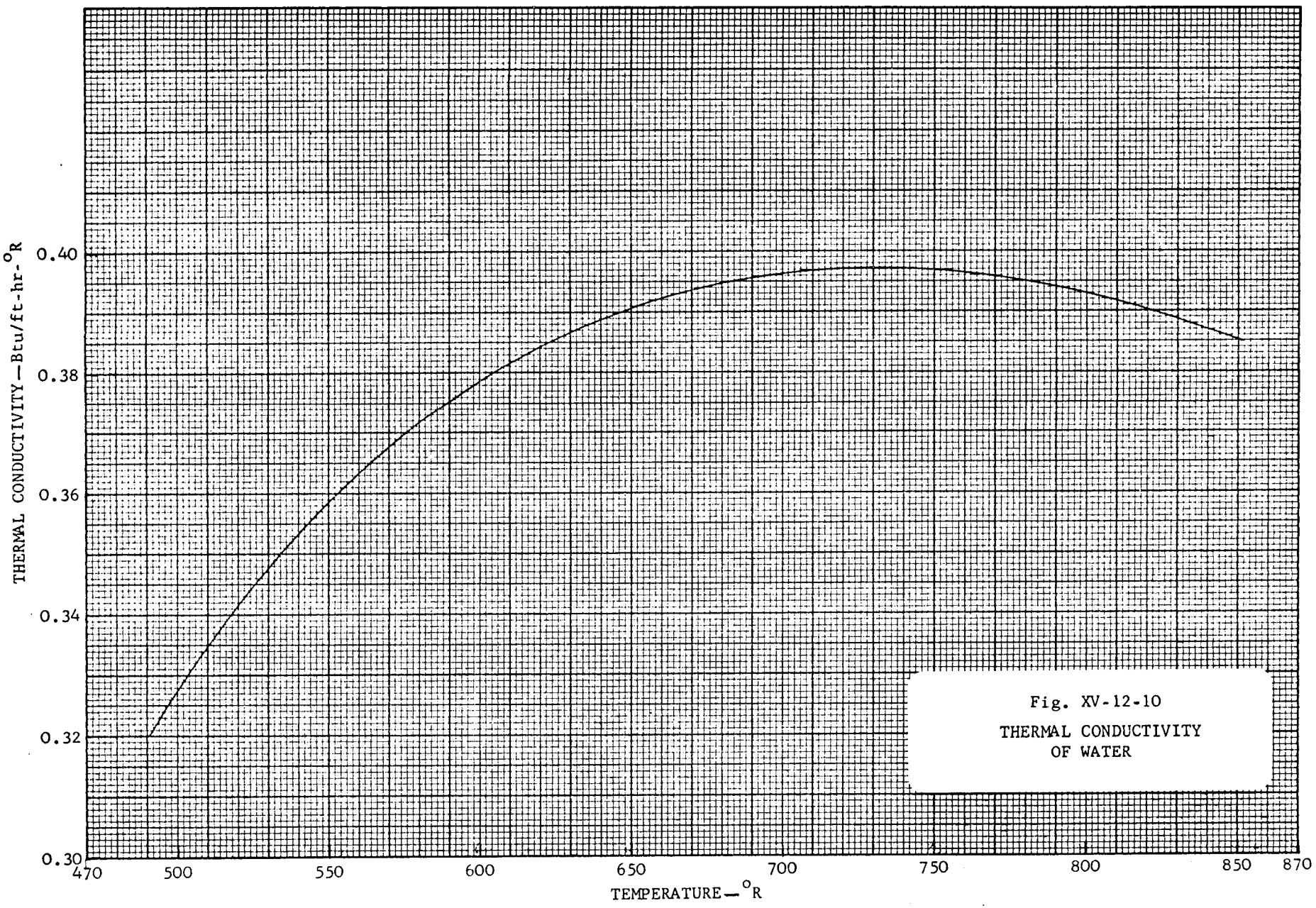


Fig. XV-12-10

THERMAL CONDUCTIVITY
OF WATER

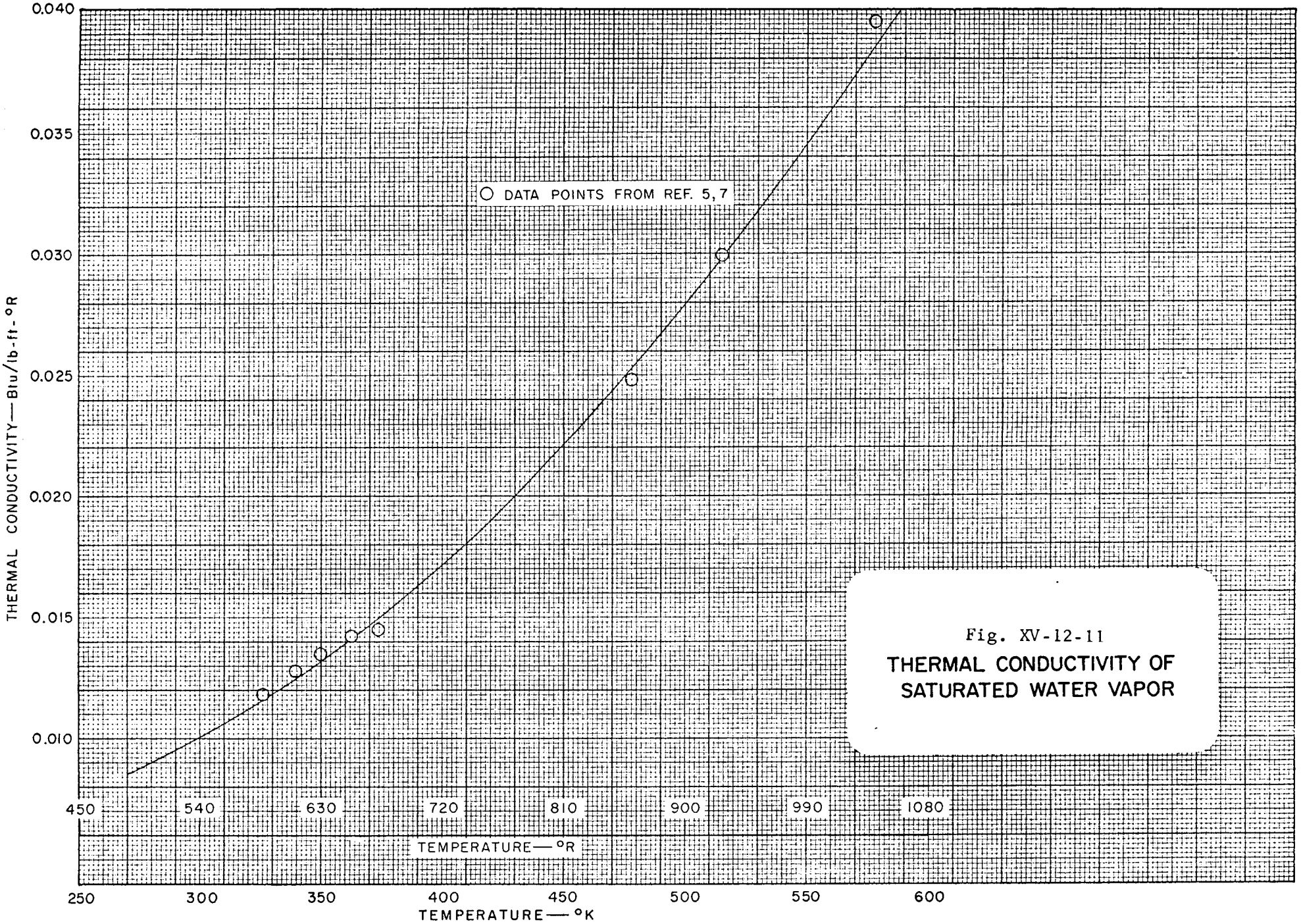


Fig. XV-12-11
THERMAL CONDUCTIVITY OF SATURATED WATER VAPOR

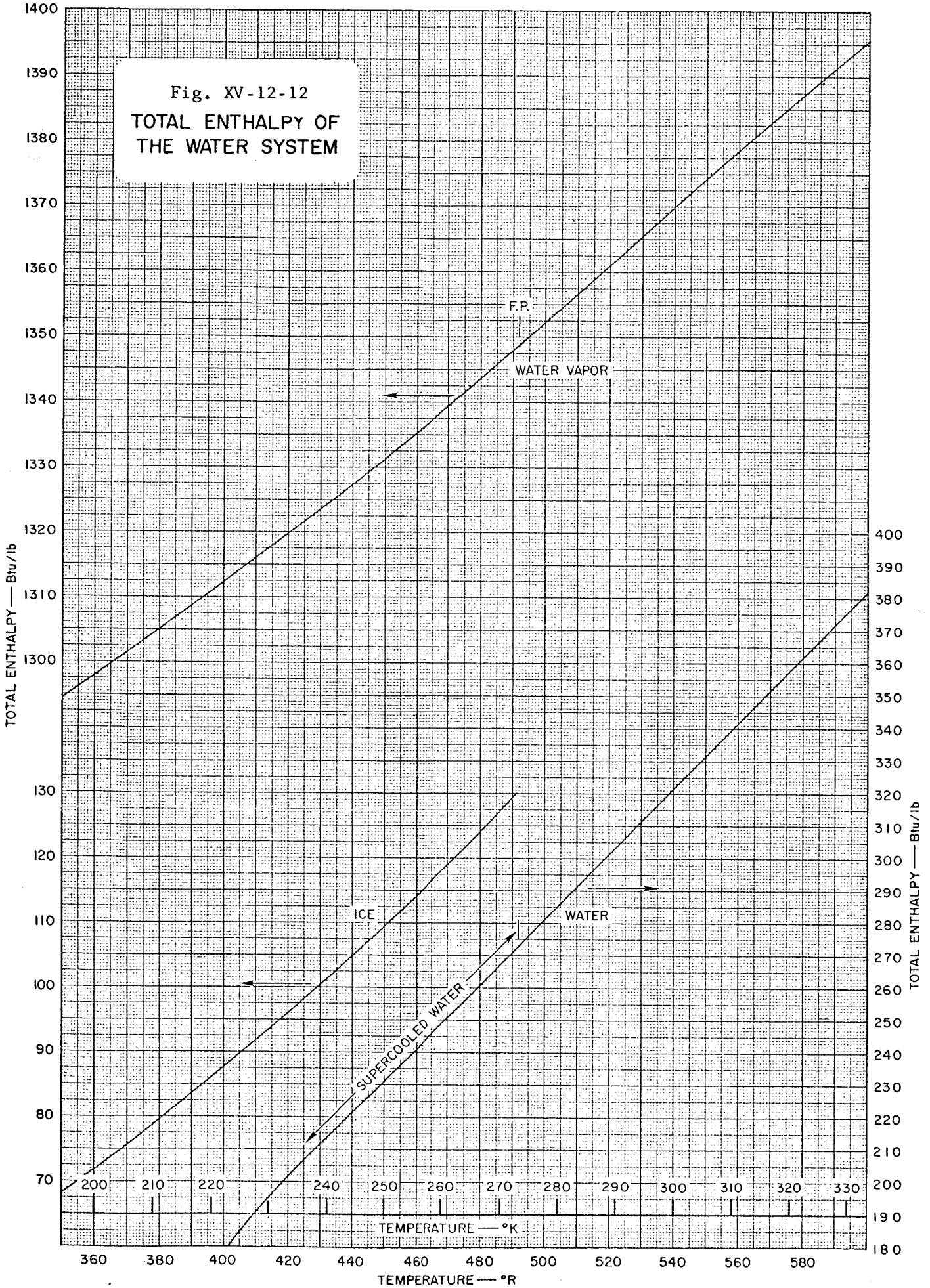


Fig. XV-12-12
TOTAL ENTHALPY OF THE WATER SYSTEM
F.P.
WATER VAPOR
ICE
WATER
SUPERCOOLED WATER
TOTAL ENTHALPY — Btu/lb
TOTAL ENTHALPY — Btu/lb
TEMPERATURE — °K
TEMPERATURE — °R
1400
1390
1380
1370
1360
1350
1340
1330
1320
1310
1300
130
120
110
100
90
80
70
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
200
210
220
240
250
260
270
280
290
300
310
320
330
360
380
400
420
440
460
480
500
520
540
560
580

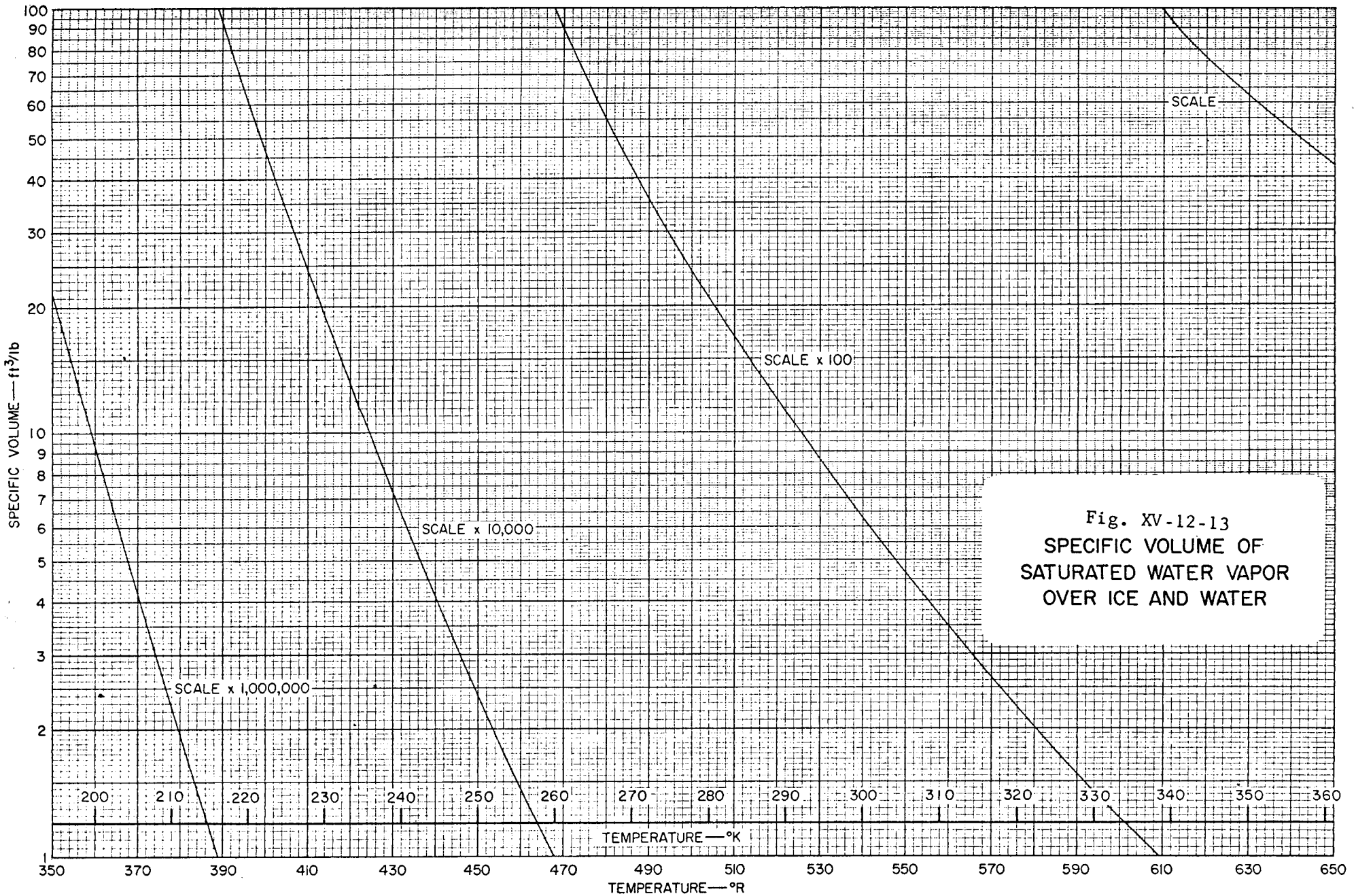


Fig. XV-12-13
SPECIFIC VOLUME OF SATURATED WATER VAPOR OVER ICE AND WATER

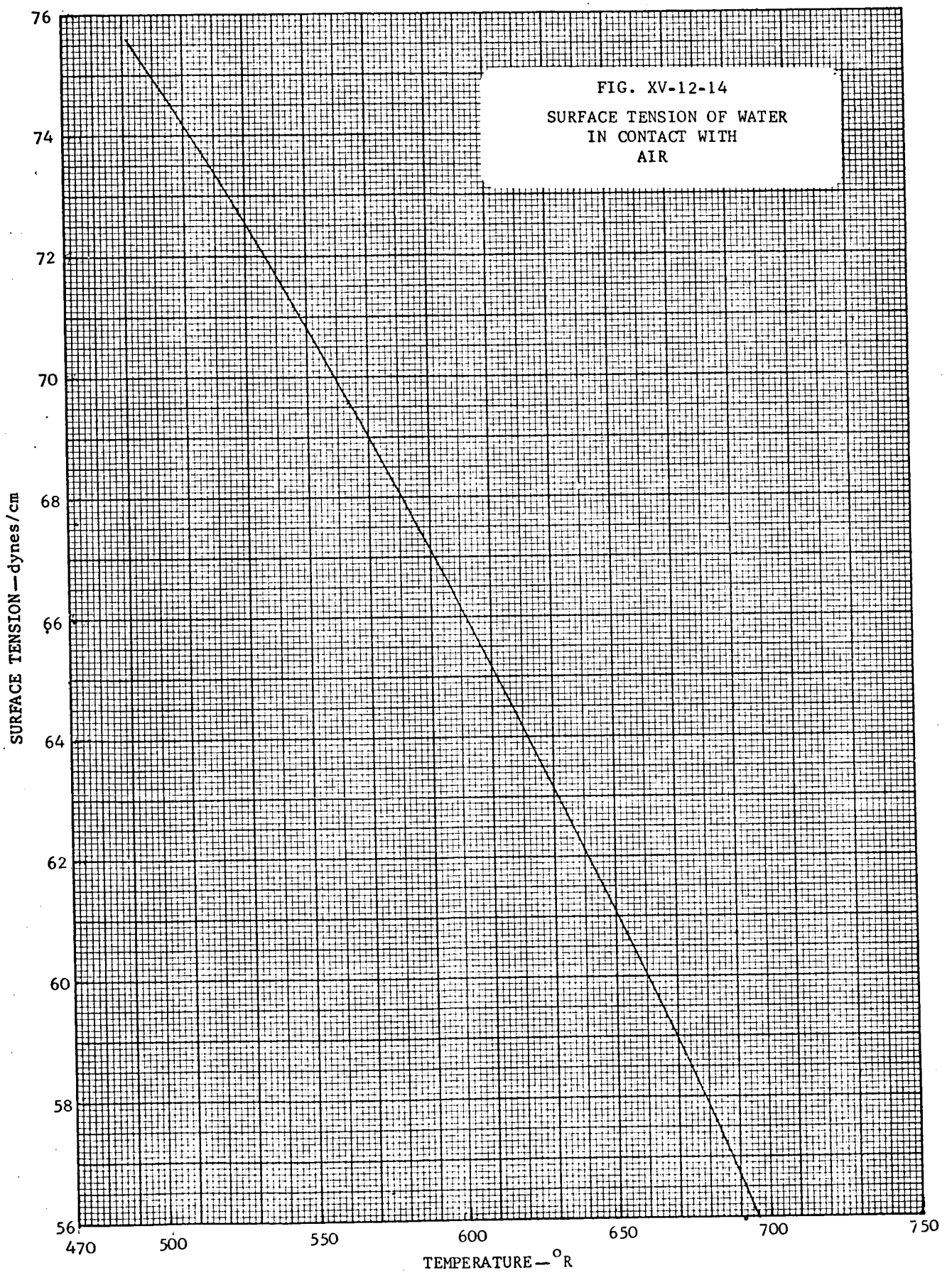


FIG. XV-12-14

SURFACE TENSION OF WATER IN CONTACT WITH AIR

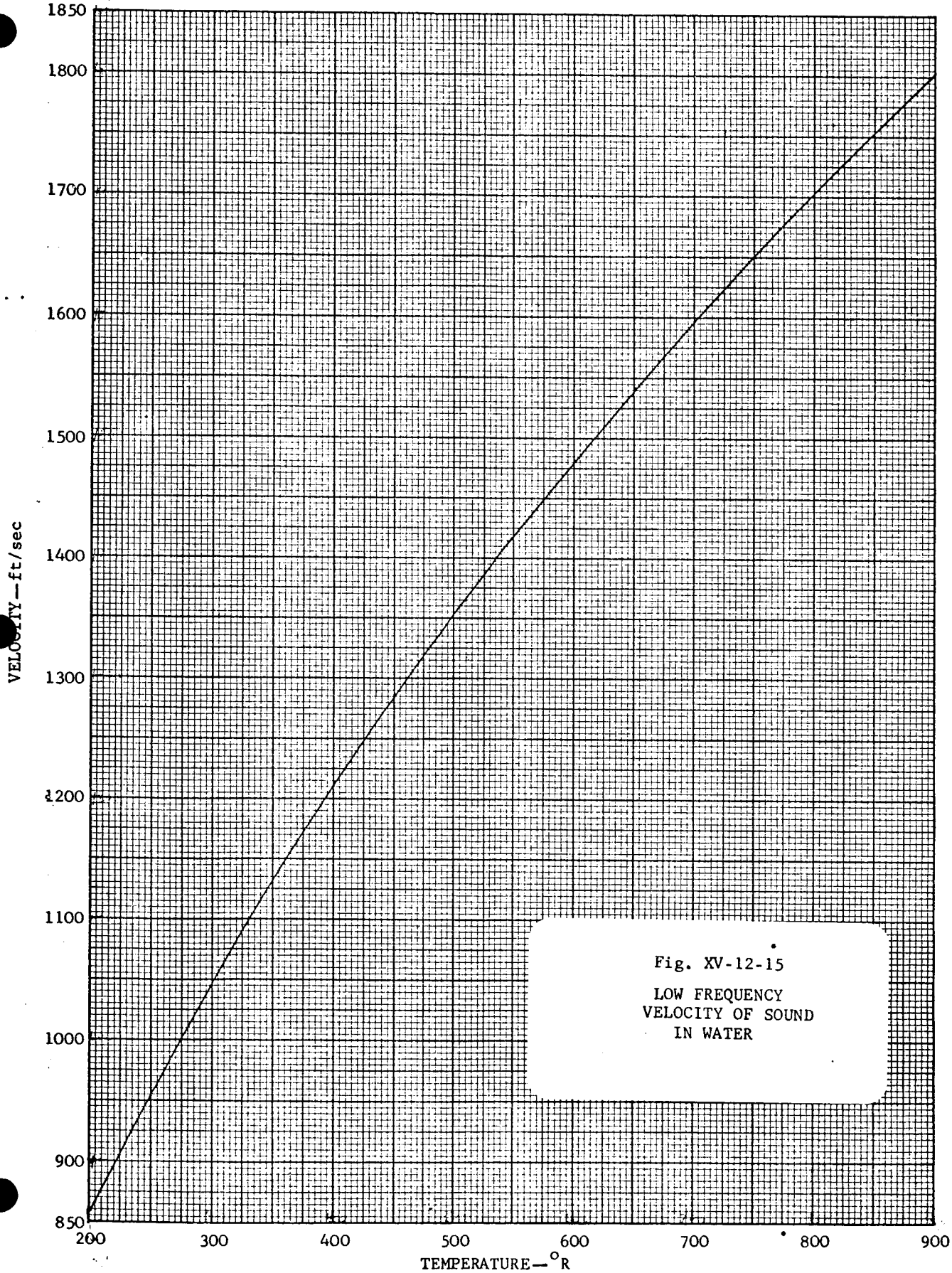


Fig. XV-12-15

LOW FREQUENCY
VELOCITY OF SOUND
IN WATER

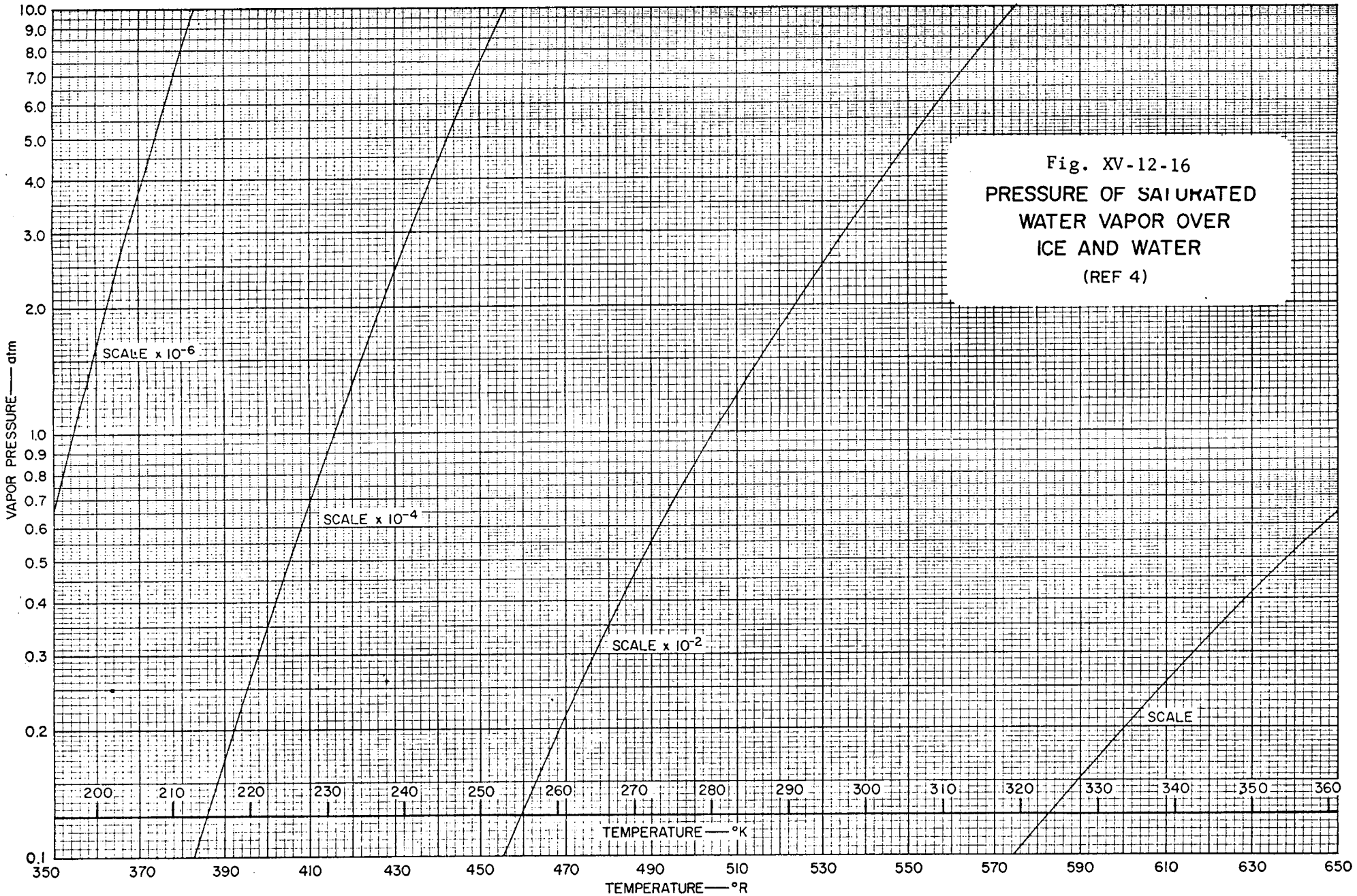


Fig. XV-12-16
PRESSURE OF SATURATED WATER VAPOR OVER ICE AND WATER
(REF 4)

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Table XV-13-1

PHYSICAL CONSTANTS

OF

PROPANE

		REF.
Molecular Weight	44.10	10
Boiling Point @ 1 atm	-43.82°F	10
Freezing Point @ 1 atm	-305.88°F	10
Specific Volume @ 70°F	8.674 cu ft/lb	10
Vapor Pressure @ 70°F (cylinder pressure)	124.3 psia	10
Specific Gravity, (Air = 1)	1.562	10
Density		
Liquid @ b.p.	0.585 lb/cu ft	10
Gas @ 32°F	0.1261 lb/cu ft	10
Critical Temperature	206.2°F	10
Critical Pressure	617.4 psia	10
Critical Density	13.735 lb/cu ft	10
Latent Heat of Vaporization @ b.p.	183.168 Btu/lb	10
Latent Heat of Fusion @ m.p.	34.38 Btu/lb	10
Specific Heat of Gas		
c_p @ 60°F	0.473 Btu/lb-°F	10
c_v @ 60°F	0.411 Btu/lb-°F	10
Specific Heat Ratio, c_p/c_v @ 60°F	1.15	10
Thermal Conductivity @ 32°F	0.0087 Btu/hr-ft-°F	10
Viscosity		
Liquid @ -80°F	1.76×10^{-4} lb/ft-sec	10
Gas @ 60°F	5.40×10^{-6} lb/ft-sec	10
Solubility in Water		
Surface Tension		

Table XV-13-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR PROPANE

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.86083	1.92265	141.4023	27.3468
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0298072	0.0307976	22.65351	0.438048
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.03379	1.06814	785.681	15.1926
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0165596	0.0171098	12.5853	0.226773
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-13-2

VAPOR PRESSURE OF LIQUID PROPANE (Ref. 1, 2, 3, 8)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
105.35	189.63	0.000019	194.26	349.67	2.036
108.25	194.85	0.000039	199.82	359.67	2.896
112.45	202.41	0.000097	205.37	369.67	4.029
			210.93	379.67	5.499
115.75	208.35	0.000193	216.48	389.67	7.365
119.25	214.62	0.000387			
124.35	223.83	0.000967			
128.35	231.03	0.001933	222.04	399.67	9.705
132.85	239.13	0.003867	227.59	409.67	12.592
			233.15	419.67	16.2
139.15	250.47	0.009668	244.26	439.67	25.4
144.35	259.83	0.01933	255.37	459.67	38.2
149.95	269.91	0.03867	266.48	479.67	55.5
158.15	284.67	0.09668	277.59	499.67	78.0
164.75	296.55	0.1933	294.26	529.67	124.0
			305.37	549.67	164.0
166.48	299.67	0.2324	316.48	569.67	212.0
172.04	309.67	0.3825			
177.59	319.67	0.6074	327.59	589.67	272.0
183.15	329.67	0.9348	333.15	599.67	305.0
188.71	339.67	1.393			

(See Figure XV-13-1,
Figure XV-13-2)

Table XV-13-3

DENSITY OF PROPANE (Ref. 12)

DENSITY-lb/ft^3							
PRESS. psia \ TEMP. °R	560	590	620	650	680	740	800
14.7	0.1094	0.1036	0.09843	0.09376	0.08953	0.08211	0.07586
50	0.3854	0.3632	0.3434	0.3261	0.3105	0.2836	0.2611
150	1.328	1.211	1.078	1.050	0.9887	0.8890	0.8032
300	29.67	27.58	2.713	2.415	2.206	1.911	1.706
500	29.96	28.07	25.59	5.81	4.56	3.579	3.069
1000	30.60	29.01	27.10	24.94	21.88	11.63	7.75
1500	31.16	29.73	28.14	26.42	24.46	19.43	13.95
2000	31.63	30.33	28.95	27.46	25.83	22.21	18.18
4000	33.18	32.09	31.05	29.98	28.84	26.59	24.37
6000	34.26	33.38	32.47	31.59	30.62	28.82	27.07

(See Figure XV-13-3

Table XV-13-4

DENSITY OF LIQUID PROPANE (Ref. 6)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
83.15	149.67	45.70	233.15	419.67	36.11
93.15	167.67	45.14	243.15	437.67	35.36
103.15	185.67	44.57	253.15	455.67	34.59
113.15	203.67	44.01	263.15	473.67	33.80
123.15	221.67	43.45	273.15	491.67	32.98
133.15	239.67	42.83	283.15	509.67	32.13
143.15	257.67	42.20	293.15	527.67	31.25
153.15	275.67	41.58	299.82	539.67	30.70
163.15	293.67	40.95	305.37	549.67	30.15
173.15	311.67	40.33	310.93	559.67	29.58
183.15	329.67	39.64	316.48	569.67	28.96
193.15	347.67	38.96	322.04	579.67	28.30
203.15	365.67	38.27	327.59	589.67	27.64
213.15	383.67	37.56	333.15	599.67	27.00
223.15	401.67	36.83			

Table XV-13-5

DENSITY OF SATURATED PROPANE VAPOR (Ref. 2)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
213.71	384.67	0.0690	283.71	519.67	0.990
216.48	389.67	0.0775	294.26	529.67	1.13
219.26	394.67	0.0885	299.82	539.67	1.30
222.04	399.67	0.111	305.37	549.67	1.49
227.59	409.67	0.129	310.93	559.67	1.69
233.15	419.67	0.163	316.48	569.67	1.92
238.71	429.67	0.203	322.04	579.67	2.18
244.26	439.67	0.250	327.59	589.67	2.48
249.82	449.67	0.307	333.15	599.67	2.78
255.37	459.67	0.369			
260.93	469.67	0.441			
266.48	479.67	0.526			
272.04	489.67	0.625			
277.59	499.67	0.730			
283.15	509.67	0.847			

Table XV-13-6

HEAT CAPACITY OF SOLID AND LIQUID PROPANE (Ref. 3)

TEMPERATURE		HEAT CAPACITY	TEMPERATURE		HEAT CAPACITY
^{o}K	^{o}R	Btu/lb-^{o}R	^{o}K	^{o}R	Btu/lb-^{o}R
15	27	0.0150	90	162	0.4581
20	36	0.0361	100	180	0.4606
25	45	0.0598	110	198	0.4631
30	54	0.0854	120	216	0.4661
35	63	0.1125	130	234	0.4697
40	72	0.1360	140	252	0.4733
45	81	0.1570	150	270	0.4774
50	90	0.1761	160	288	0.4819
55	99	0.1944	170	306	0.4869
60	108	0.2119	180	324	0.4928
65	117	0.2286	190	432	0.4996
70	126	0.2443	200	360	0.5069
75	135	0.2590	210	378	0.5148
80	144	0.2731	220	396	0.5232
85	153	0.2867	230	414	0.5327
85.45	153.81	Melting Point	231.04	415.87	Boiling Point

(See Figure XV-13-4)

Table XV-13-7

HEAT CAPACITY OF PROPANE GAS (Ref. 4)

TEMPERATURE		HEAT CAPACITY--Btu/lb-^{o}R		
^{o}K	^{o}R	1 atm	10 atm	20 atm
240	432	0.340		
260	468	0.361		
280	561	0.381		
300	540	0.401		
320	576	0.424		
340	612	0.444	0.483	
360	648	0.465	0.492	
380	684	0.488	0.508	0.542
400	720	0.510	0.526	0.549
420	756	0.533	0.547	0.565
440	792	0.556	0.567	0.581
460	828	0.578	0.587	0.599
480	864	0.599	0.608	0.617
500	906	0.617	0.626	0.635
520	936	0.637	0.646	0.653
540	976	0.653	0.660	0.667
560	1008	0.669	0.676	0.680
580	1041	0.683	0.687	0.692
600	1080	0.696	0.701	0.705

(See Figure XV-13-5)

Table XV-13-8

SURFACE TENSION OF LIQUID PROPANE (Ref. 6)

TEMPERATURE		SURFACE TENSION
^oK	^oR	lb/ft^2
143.15	257.8	0.0581
153.15	275.4	0.0549
163.15	293.4	0.0520
173.15	311.4	0.0489
183.15	329.4	0.0460
193.15	347.4	0.0430
203.15	365.4	0.0401
213.17	383.4	0.0373
223.15	401.4	0.0344
233.15	419.4	0.0316

(See Figure XV-13-8)

Table XV-13-9

VISCOSITY OF LIQUID PROPANE (Ref. 2, 6, 7)

TEMPERATURE		ABSOLUTE VISCOSITY	PRESSURE
^oK	^oR	micro-poises	atm
213.15	383.67	2560	1 (total)
223.15	401.67	2228	1 (total)
277.59	499.67	1170	saturated
288.71	519.67	1060	saturated
299.82	539.67	970	saturated
310.93	559.67	860	saturated
322.04	579.67	770	saturated
333.15	599.67	670	saturated
344.26	619.67	573	saturated
360.93	619.67	440	saturated

(See Figure XV-13-9)

Table XV-13-10

VISCOSITY OF PROPANE AT VARIOUS PRESSURES (Ref. 11)

TEMP. °F	70.0	100	130	160	190	220	250	280	400	460
PRESSURE psia	VISCOSITY— poises									
14.7	80	85	89	93	98	102	106	110	126	133
100	81	86	91	96	100	105	110	114	128	135
200	1,010	848	93	98	102	107	112	116	130	137
300	1,025	863	710	102	106	110	114	119	132	139
400	1,040	877	725	562	112	116	119	123	134	141
500	1,055	891	741	588	127	125	125	129	137	143
600	1,070	905	755	610	454	140	134	135	140	146
800	1,095	932	785	650	520	345	178	157	149	153
1,000	1,125	956	814	682	560	432	295	208	162	162
1,250	1,157	987	846	718	605	495	390	297	185	178
1,500	1,189	1,017	877	753	643	543	447	362	212	197
1,750	1,218	1,045	906	785	675	580	492	412	242	218
2,000	1,247	1,074	935	815	705	615	530	453	272	240
2,500	1,300	1,126	988	870	762	675	593	518	329	284
3,000	1,351	1,176	1,037	922	815	725	645	575	379	327
4,000	1,445	1,275	1,132	1,016	910	820	740	667	469	405
5,000	1,538	1,367	1,220	1,102	996	903	820	748	546	476
6,000	1,627	1,450	1,305	1,182	1,077	981	895	822	615	540
7,000	1,715	1,535	1,385	1,257	1,155	1,053	964	887	680	602
8,000	1,802	1,610	1,463	1,333	1,231	1,120	1,028	950	741	660

Table XV-13-11

HEAT OF VAPORIZATION OF LIQUID PROPANE (Ref. 2)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
216.48	389.67	189.0	272.04	489.67	163.4
222.04	399.67	185.5	277.59	499.67	160.3
227.59	409.67	183.2	283.15	509.67	156.5
233.15	419.67	180.8	288.71	519.67	152.6
238.71	429.67	178.7	294.26	529.67	148.3
244.26	439.67	176.2	299.82	539.67	145.1
249.82	449.67	173.2	305.37	549.67	140.0
255.37	459.67	171.5	310.93	559.67	135.8
260.93	469.67	167.2	322.04	579.67	125.4
266.48	479.67	166.3	333.15	599.67	112.5

(See Figure XV-3-10)

Table XV-13-12

TOTAL ENTHALPY VALUES AND SPECIFIC VOLUMES FOR THE PROPANE SYSTEM
(Computed from References 1, 2, 3, 8, 9)

TEMPERA-TURE	TOTAL ENTHALPY—Btu/lb			SPEC. VOL. VAPOR	TEMPERA-TURE	TOTAL ENTHALPY—Btu/lb			SPEC. VOL. VAPOR
°R	Solid	Liquid	Vapor	ft^3/lb	°R	Solid	Liquid	Vapor	ft^3/lb
0	0				370		159.1	352.4	21.4
40	0.50				380		164.3	355.4	15.2
60	2.00				390		169.3	358.3	12.3
80	4.62				400		174.4	360.8	9.55
100	8.14				410		179.5	364.0	7.55
120	12.46				420		184.7	366.9	6.05
140	17.48				430		190.1	369.9	4.93
150		53.90			440		195.6	373.0	4.03
153.83	21.30	55.65			450		201.6	376.3	3.33
160		58.40			460		206.8	378.6	2.75
170		62.90			470		212.4	381.2	2.28
180		67.40			480		218.3	384.0	1.92
190		71.80		2 311 920.	490		223.9	386.6	1.62
200		76.30	311.1	666 740.	500		230.2	389.6	1.37
210		81.00	313.	217 470.	510		235.3	391.3	1.17
220		85.70	315.	82 368.	520		241.3	393.6	0.99
230		90.40	317.	31 623.	530		247.4	395.7	0.86
240		95.10	319.	13 906.	540		253.6	397.8	0.74
250		99.90	322.	6 427.3	550		259.9	399.7	0.64
260		104.8	324.	3 163.7	560		266.3	402.7	0.55
270		109.7	326.	1 663.5	570		272.9	403.6	0.475
280		114.5	329.	896.6	580		279.7	405.3	0.41
290		119.5	331.	526.7	590		286.9	406.9	0.355
300		124.3	334.	313.3	600		294.4	408.4	0.32
310		129.2	336.	203.9					
320		134.2	339.	129.8					
330		139.1	341.	87.8					
340		144.2	344.	57.0					
350		149.1	347.	40.0					
360		154.2	350.	29.2					

(See Figure XV-13-12,
Figure XV-13-13)

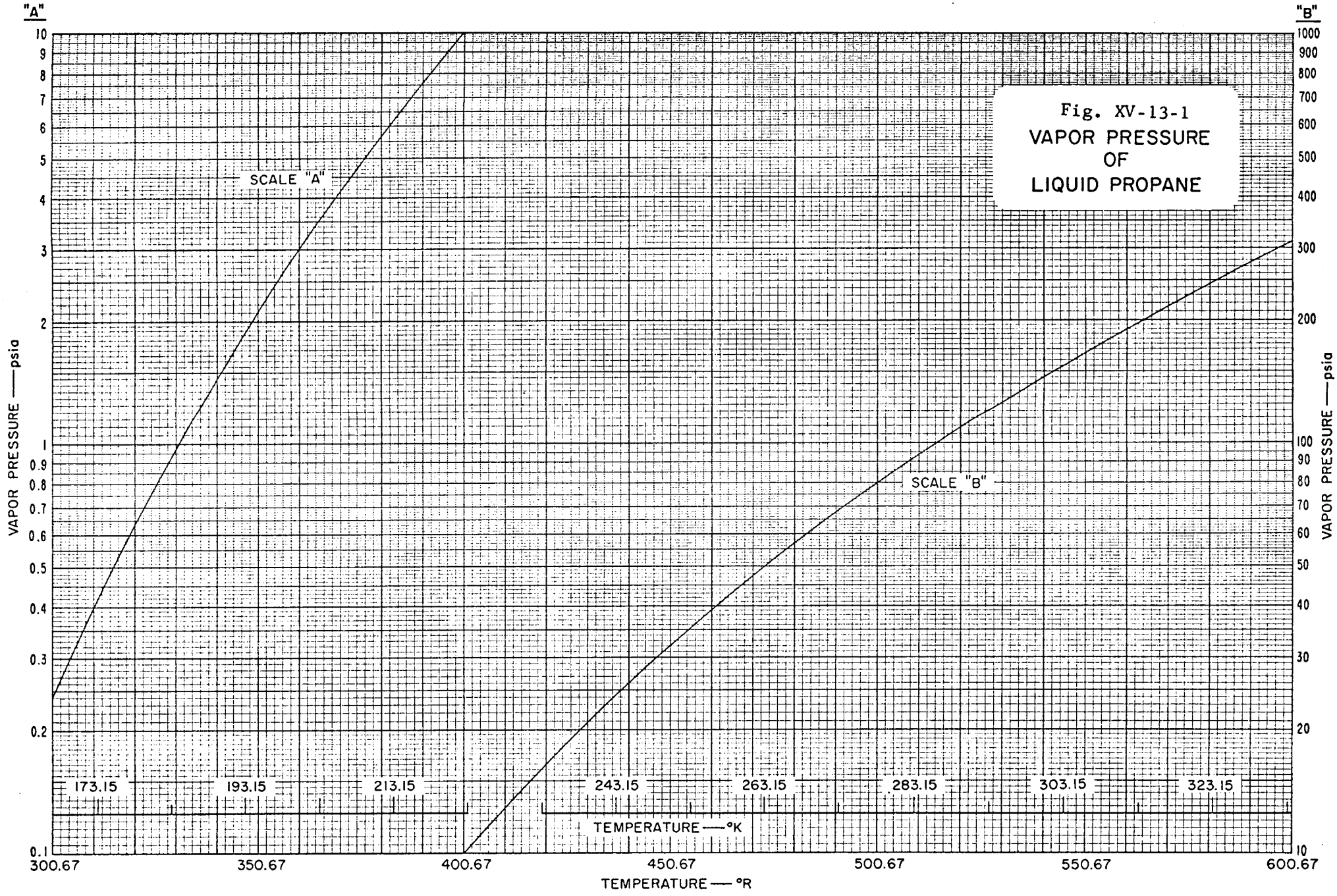


Fig. XV-13-1
VAPOR PRESSURE
OF
LIQUID PROPANE

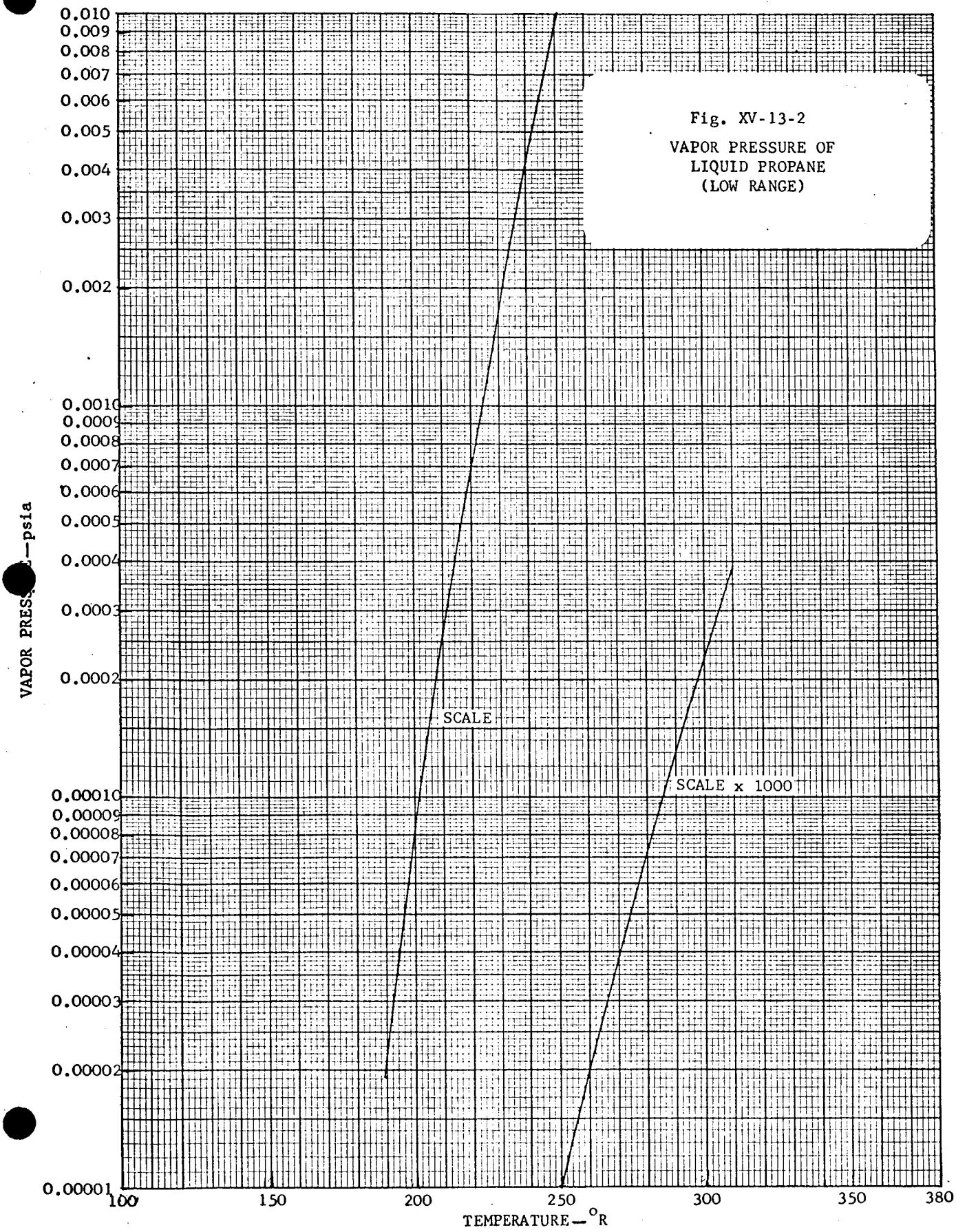
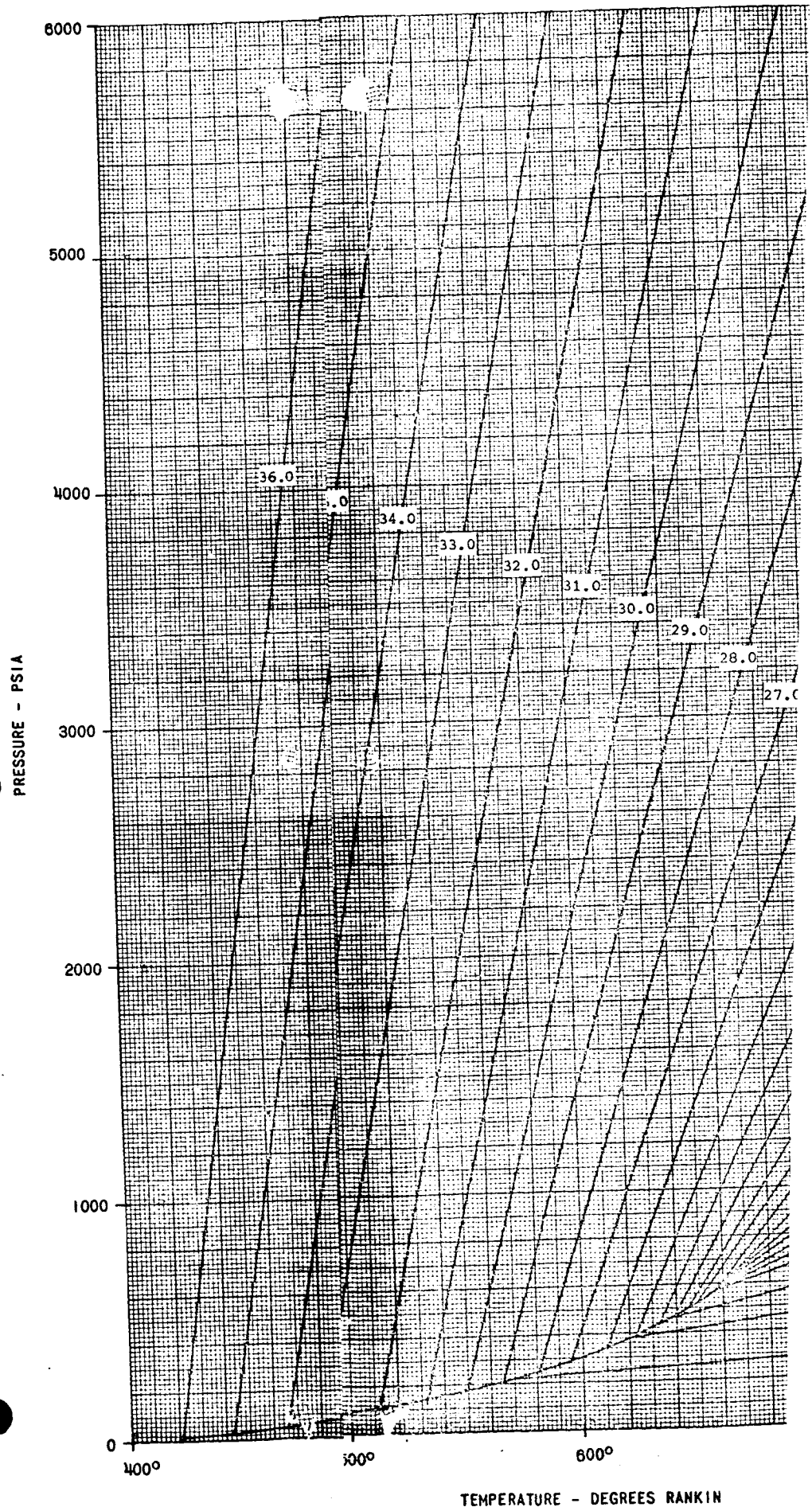


Fig. XV-13-2

VAPOR PRESSURE OF LIQUID PROPANE (LOW RANGE)


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
36.0
.0
34.0
33.0
32.0
31.0
30.0
29.0
28.0
27.0
400°
500°
600°
TEMPERATURE - DEGREES RANKIN

XU-13-2-1

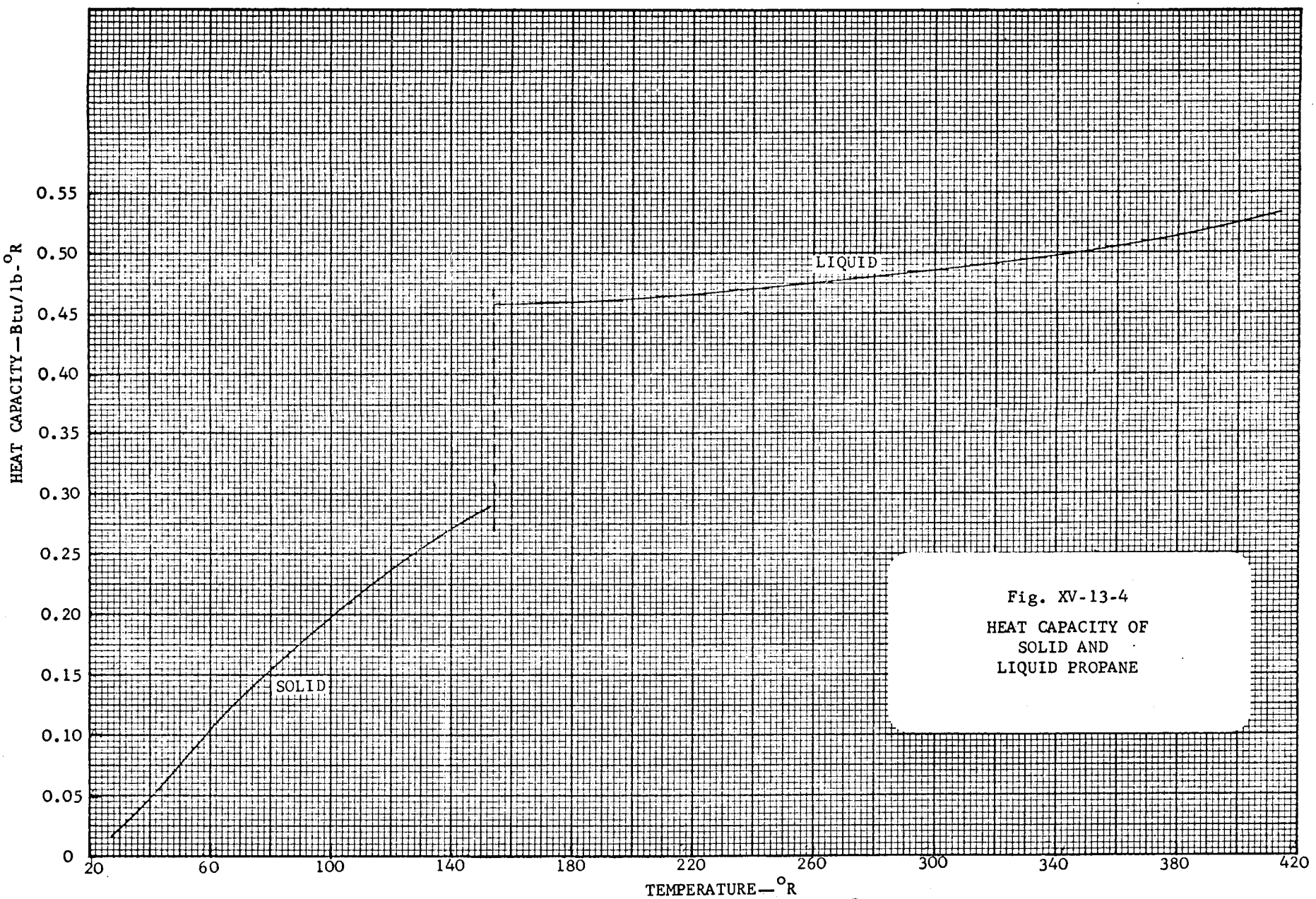


Fig. XV-13-4

HEAT CAPACITY OF SOLID AND LIQUID PROPANE

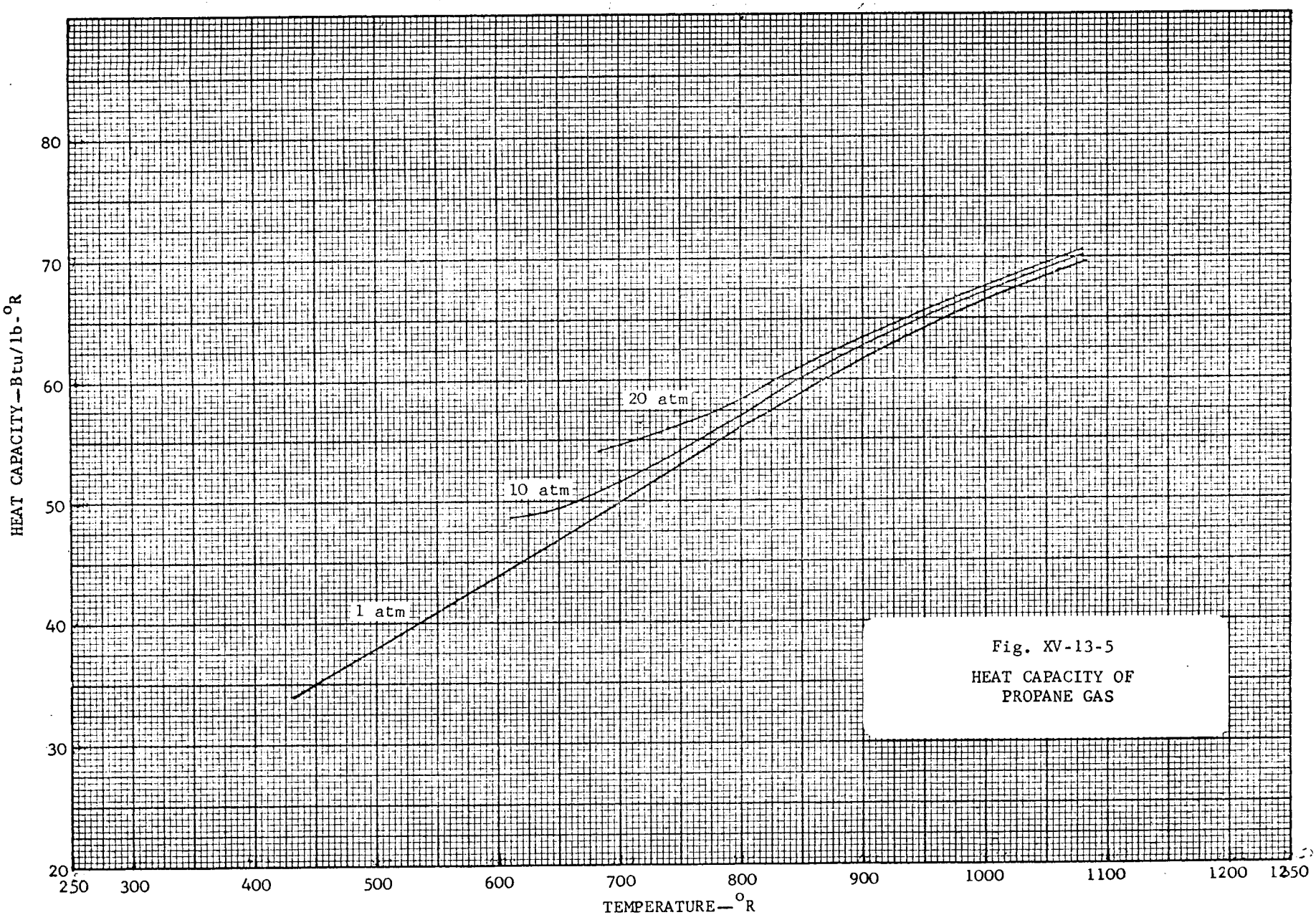


Fig. XV-13-5

HEAT CAPACITY OF PROPANE GAS

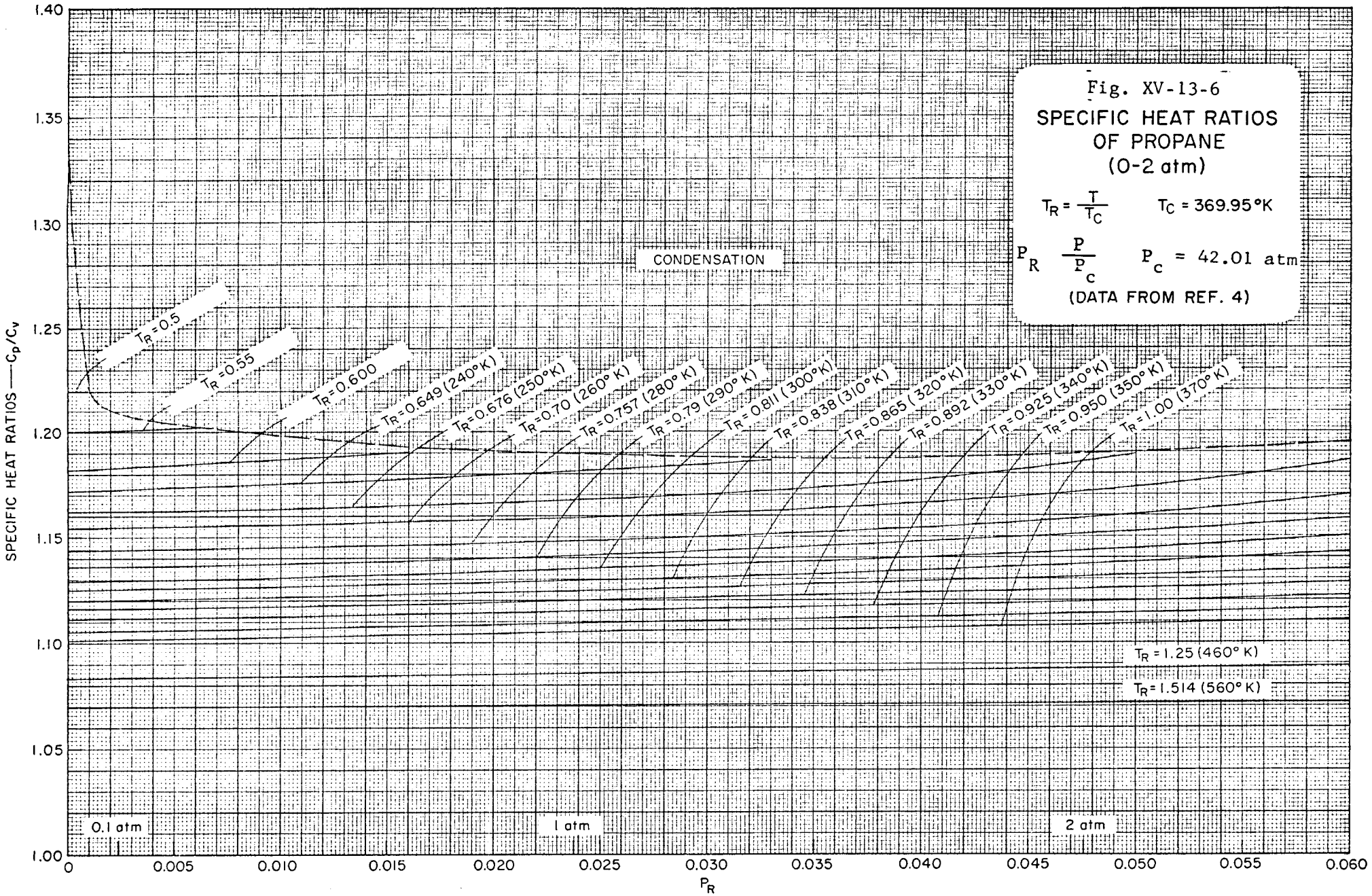


Fig. XV-13-6
SPECIFIC HEAT RATIOS OF PROPANE (0-2 atm)
$T_R = \frac{T}{T_C}$ $T_C = 369.95°K$
$P_R \frac{P}{P_c}$ $P_c = 42.01$ atm
(DATA FROM REF. 4)
CONDENSATION
$T_R = 0.5$
$T_R = 0.55$
$T_R = 0.600$
$T_R = 0.649$ (240° K)
$T_R = 0.676$ (250° K)
$T_R = 0.70$ (260° K)
$T_R = 0.757$ (280° K)
$T_R = 0.79$ (290° K)
$T_R = 0.811$ (300° K)
$T_R = 0.838$ (310° K)
$T_R = 0.865$ (320° K)
$T_R = 0.892$ (330° K)
$T_R = 0.925$ (340° K)
$T_R = 0.950$ (350° K)
$T_R = 1.00$ (370° K)
$T_R = 1.25$ (460° K)
$T_R = 1.514$ (560° K)
0.1 atm
1 atm
2 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050
0.055
0.060

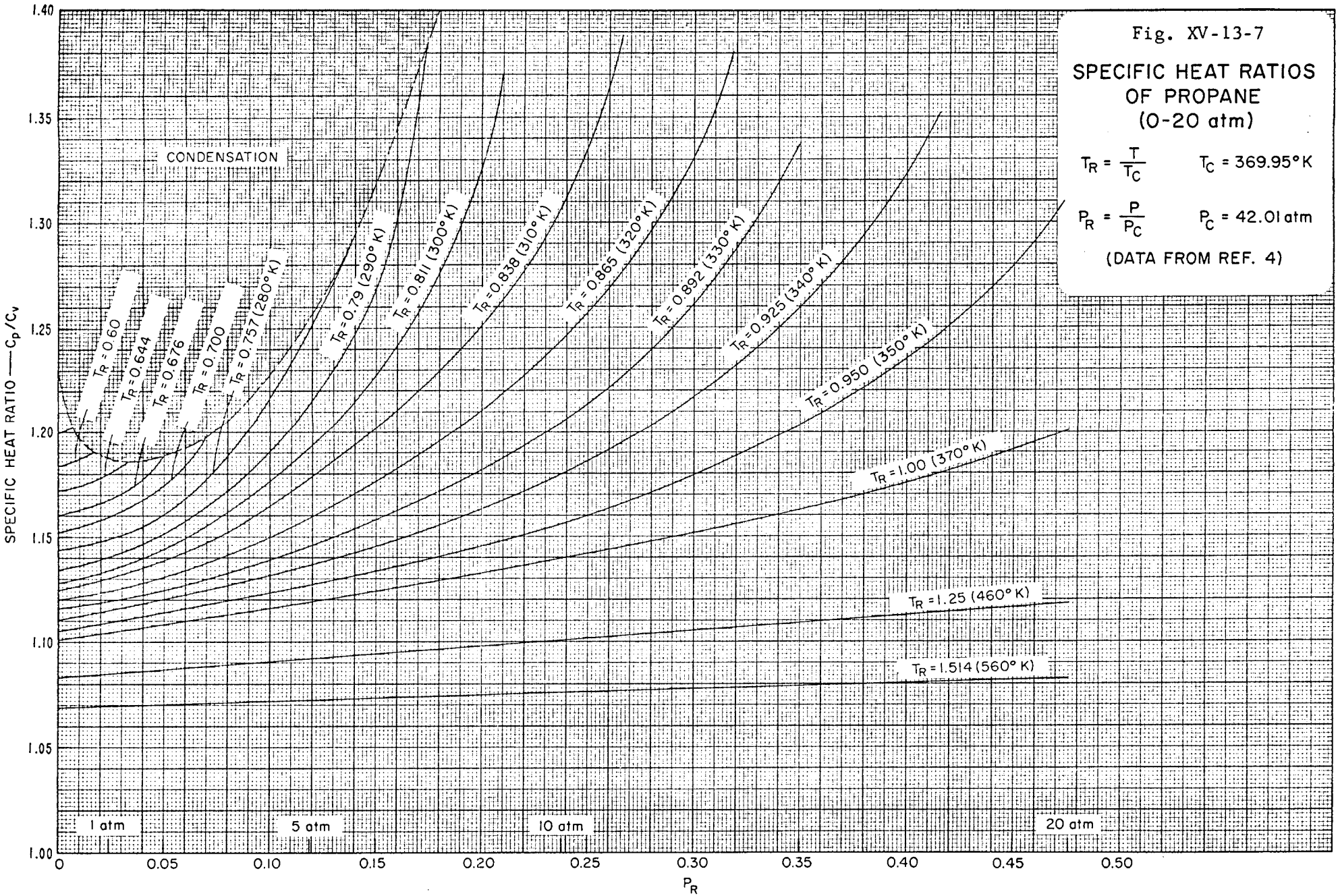


Fig. XV-13-7
SPECIFIC HEAT RATIOS OF PROPANE (0-20 atm)
$T_R = \frac{T}{T_C}$ T_C = 369.95°K
$P_R = \frac{P}{P_C}$ P_C = 42.01 atm
(DATA FROM REF. 4)
CONDENSATION
T_R = 0.60
T_R = 0.644
T_R = 0.676
T_R = 0.700
T_R = 0.757 (280° K)
T_R = 0.79 (290° K)
T_R = 0.811 (300° K)
T_R = 0.838 (310° K)
T_R = 0.865 (320° K)
T_R = 0.892 (330° K)
T_R = 0.925 (340° K)
T_R = 0.950 (350° K)
T_R = 1.00 (370° K)
T_R = 1.25 (460° K)
T_R = 1.514 (560° K)
1 atm
5 atm
10 atm
20 atm
SPECIFIC HEAT RATIO — C_p/C_v
P_R
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

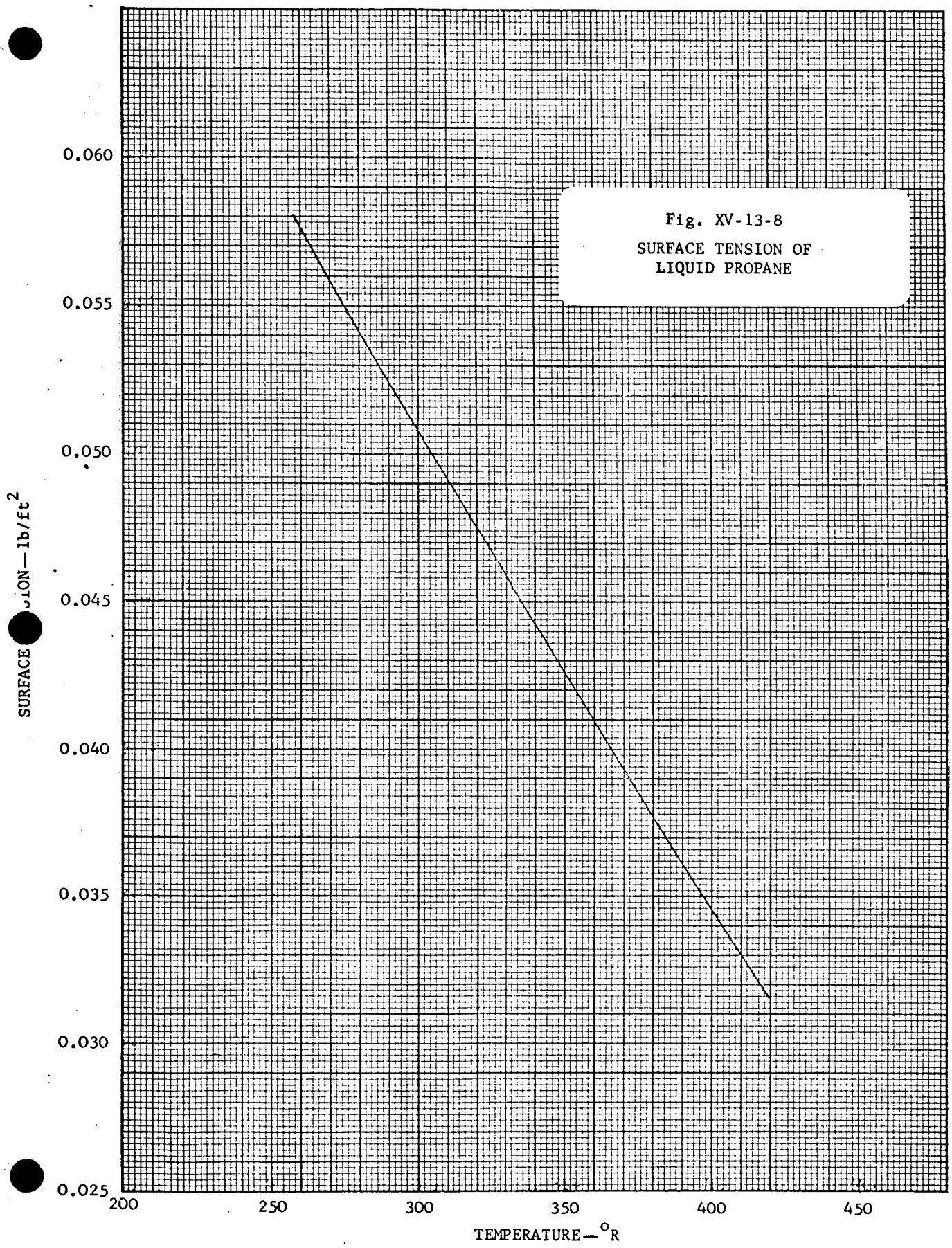


Fig. XV-13-8

SURFACE TENSION OF LIQUID PROPANE

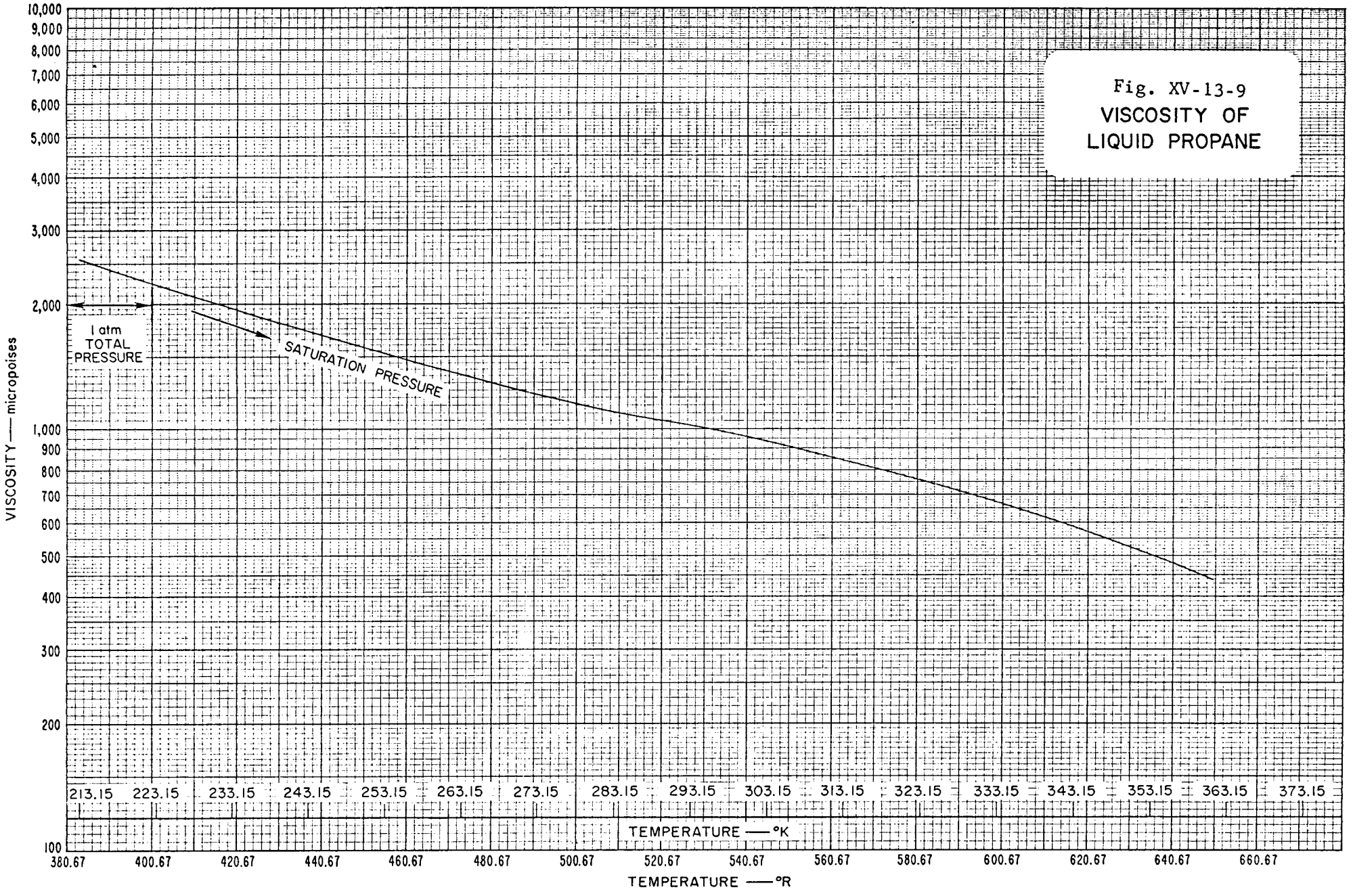


Fig. XV-13-9
VISCOSITY OF
LIQUID PROPANE

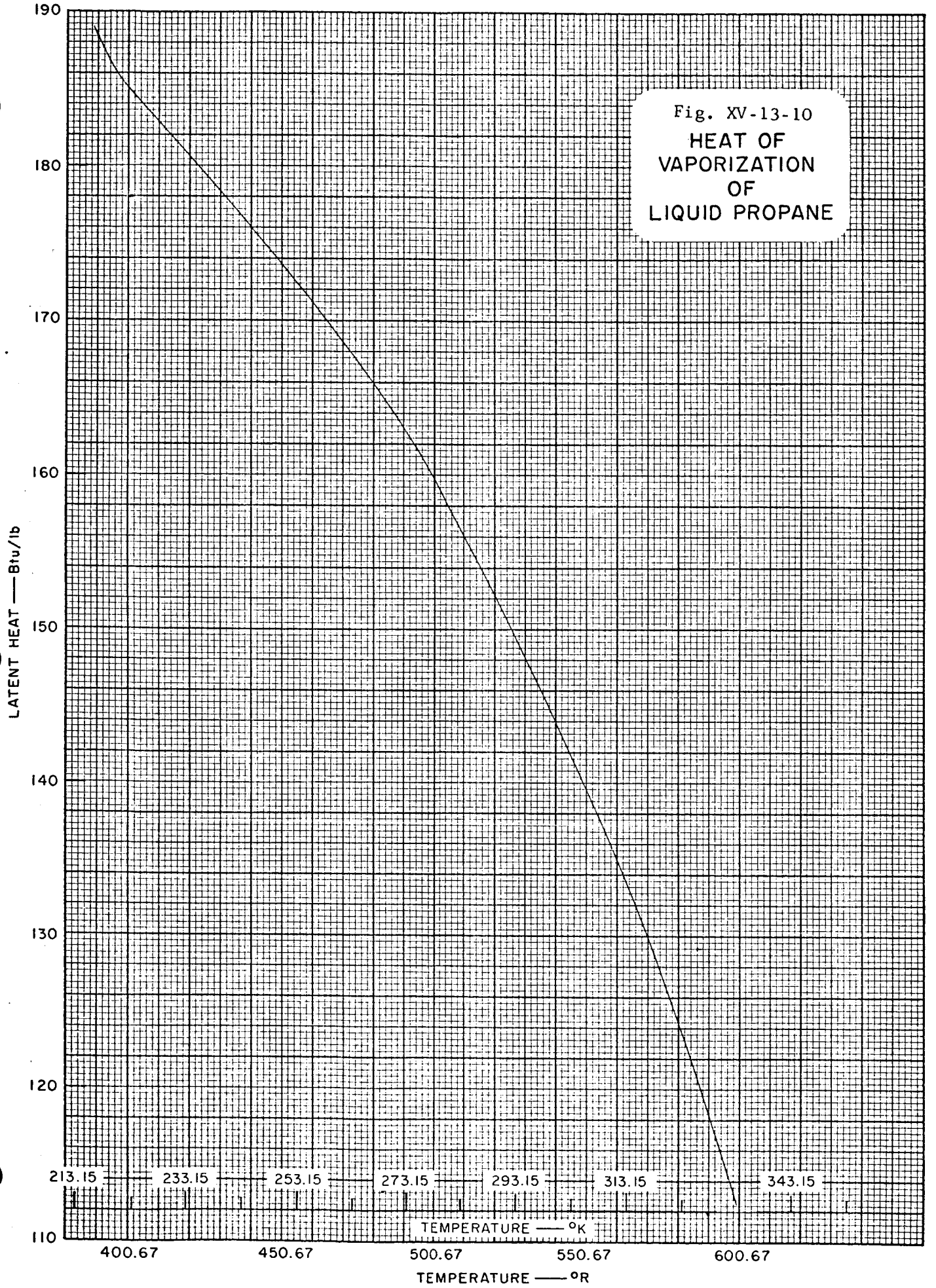


Fig. XV-13-10
HEAT OF VAPORIZATION OF LIQUID PROPANE

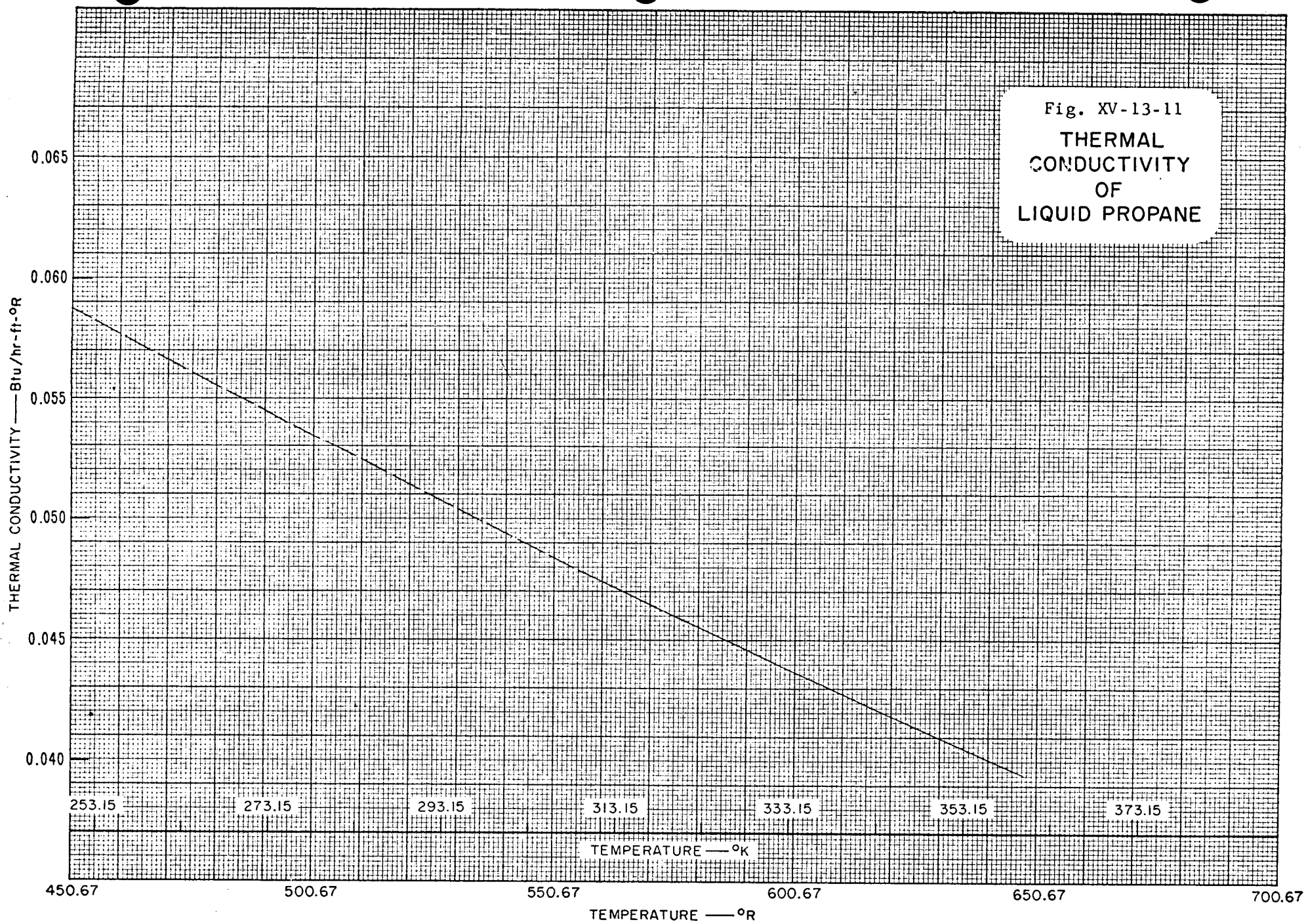


Fig. XV-13-11
THERMAL CONDUCTIVITY OF LIQUID PROPANE
THERMAL CONDUCTIVITY —— Btu/hr-ft-°R
0.065
0.060
0.055
0.050
0.045
0.040
253.15
273.15
293.15
313.15
333.15
353.15
373.15
TEMPERATURE —— °K
450.67
500.67
550.67
600.67
650.67
700.67
TEMPERATURE —— °R

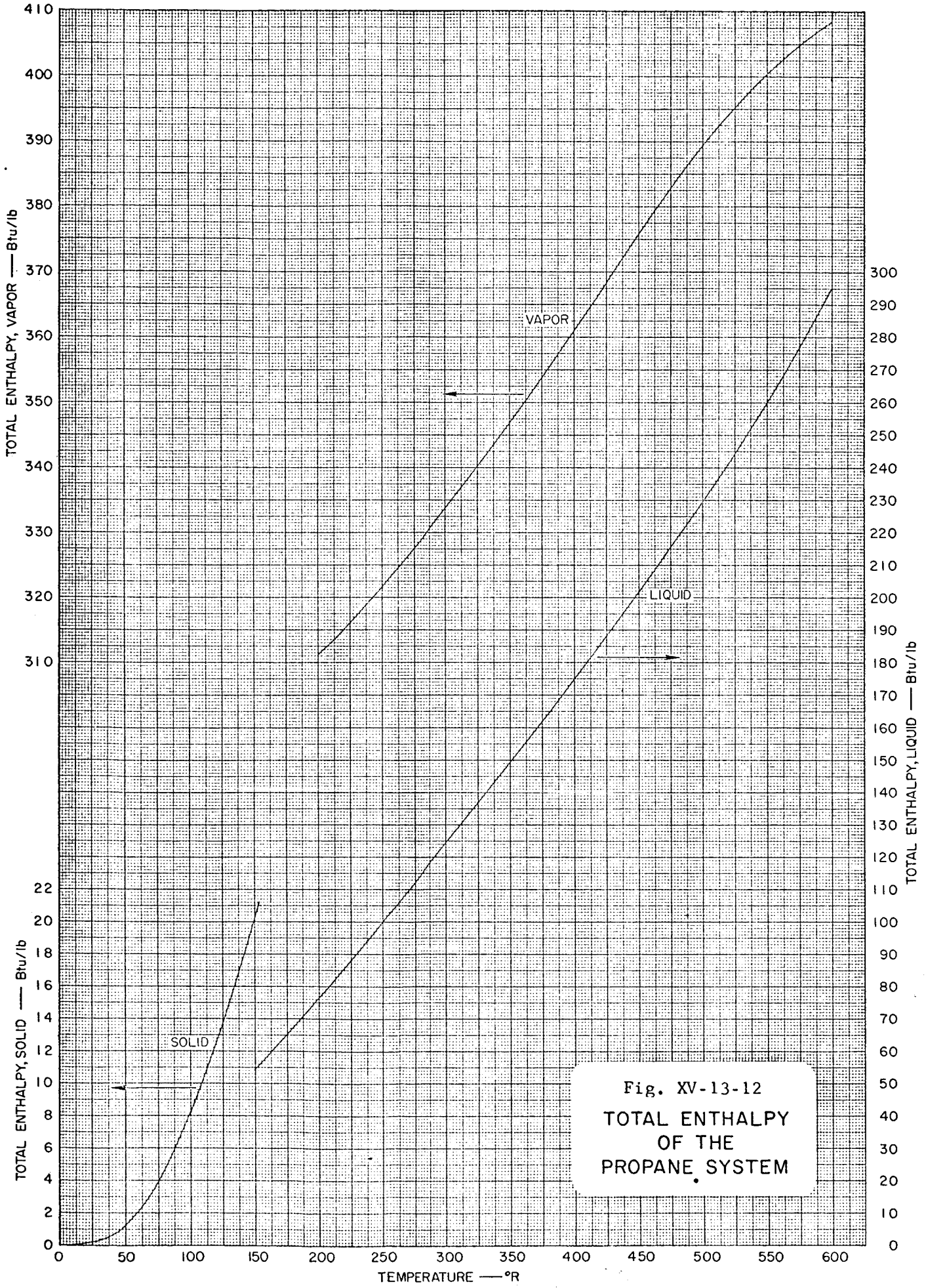


Fig. XV-13-12

TOTAL ENTHALPY OF THE PROPANE SYSTEM

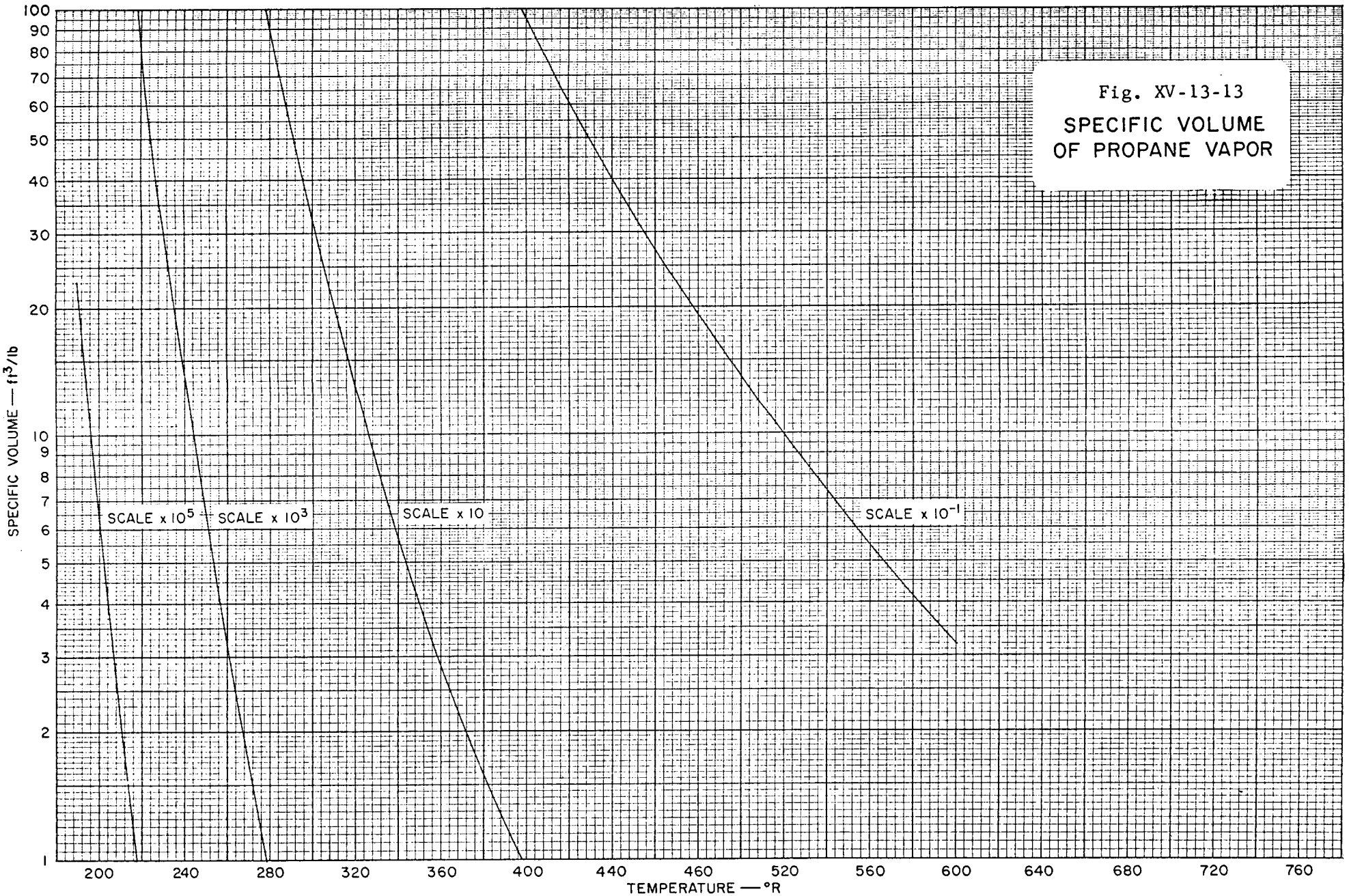


Fig. XV-13-13

SPECIFIC VOLUME OF PROPANE VAPOR

XV-13 PROPANE REFERENCES

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Table XV-14-1

PHYSICAL CONSTANTS

OF

n-BUTANE

		REF.
Molecular Weight	58.12	5
Boiling Poimt @ 1 atm	31.1°F	5
Freezing Point @ 1 atm	-217.3°F	5
Specific Volume @ 70°F	6.45 cu ft/lb	5
Vapor Pressure @ 70°F (cylinder pressure)	31.0 psia	5
Specific Gravity, (Air = 1)	2.07	5
Density		
Liquid @ 70°F	36.06 lb/cu ft	6
Gas @ 70°F	0.347 lb/cu ft	6
Critical Temperature	306°F	5
Critical Pressure	550.4 psia	5
Critical Density	14.047 lb/cu ft	5
Latent Heat of Vaporization @ b.p.	165.76 Btu/lb	5
Latent Heat of Fusion @ m.p.	34.51 Btu/lb	4
Specific Heat of Gas		
c_p @ 60°F	0.459 Btu/lb-°F	8
c_v @ 60°F	0.414 Btu/lb-°F	8
Specific Heat Ratio, c_p/c_v @ 60°F	1.108	8
Thermal Conductivity		
Viscosity		
Liquid @ 60°F	1.21×10^{-4} lb/ft-sec	8
Gas @ 58.5°F	5.65×10^{-6} lb/ft-sec	5
Solubility in Water		
Surface Tension @ 68°F	8.50×10^{-4} lb/ft	5

Table XV-14-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR n-BUTANE
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.41185	1.45876	1073.06	20.7486
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0226155	0.0233668	17.1877	0.332357
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.784361	0.810423	596.114	11.5270
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0125641	0.0129816	9.54874	0.184642
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-14-2

VAPOR PRESSURE OF n-BUTANE (Ref. 2, 4)

TEMPERATURE		PRESSURE	TEMPERATURE		PRESSURE
°K	°R	psia	°K	°R	psia
127.65	229.77	0.000019	238.71	429.67	3.273
131.15	236.07	0.000039	244.26	439.67	4.326
135.85	244.53	0.000097	249.82	449.67	5.64
139.95	251.91	0.000193	255.37	459.67	7.25
144.25	259.65	0.000387	260.93	469.67	9.20
149.95	269.91	0.000967	266.48	479.67	11.56
154.75	278.55	0.001933	272.04	489.67	14.36
159.85	287.73	0.003867	277.59	499.67	17.66
166.95	300.51	0.009668	283.14	509.67	21.53
172.85	311.13	0.01933	288.70	519.67	26.3
179.25	322.65	0.03867	294.26	529.67	31.6
188.45	339.21	0.09668	299.82	539.67	37.6
195.85	352.53	0.1933	305.37	549.67	44.5
200.37	360.67	0.2845	310.92	559.67	52.2
205.37	369.67	0.422	316.48	569.67	60.8
210.92	379.69	0.625	322.03	579.67	70.8
216.48	389.67	0.906	327.59	589.67	81.4
222.03	399.67	1.285	333.15	599.67	92.6
227.59	409.67	1.787			
233.15	419.67	2.439			

(See Figure XV-14-1,
Figure XV-14-2)

Table XV-14-3

DENSITY OF n-BUTANE (Ref. 9, 10, 11)

DENSITY-lb/ft^3							
TEMP. °R \ PRESS. psia	500	1000	2000	3000	4000	5000	6000
550	35.64	35.97	36.62	36.76			
600	33.55	34.00	34.84	35.48	36.05	36.52	36.96
650	31.05	31.88	32.91	33.80	34.52	35.14	35.60
700	28.02	29.36	31.00	32.06	32.89	33.65	34.25
750	22.00	26.11	28.81	30.30	31.37	32.16	32.87
800	5.28	21.30	26.38	28.46	29.79	30.82	31.57
850	4.29	14.40	23.65	26.45	28.15	29.41	30.38
900	3.77	10.18	20.92	24.50	26.50	27.98	29.12
950	3.32	8.29	18.35	22.54	24.95	26.52	27.85

(See Figure XV-14-3)

Table XV-14-4

DENSITY OF LIQUID n-BUTANE (Ref. 4)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
138.71	249.67	45.9	222.03	399.67	40.72
144.26	259.67	45.6	227.59	409.67	40.39
149.82	269.67	45.3	233.15	419.67	40.05
155.37	279.67	44.9	238.71	429.67	39.71
160.93	289.67	44.6	244.26	439.67	39.37
166.48	299.67	44.21	249.82	449.67	39.02
172.04	309.67	43.82	255.37	459.67	38.67
177.59	319.67	43.45	260.93	469.67	38.32
183.15	329.67	43.07	266.48	479.67	37.96
188.70	339.67	42.73	272.04	489.67	37.60
194.26	349.67	42.39	277.59	499.67	37.24
199.81	359.67	42.05	283.14	509.67	36.88
205.37	369.67	41.71	288.70	519.67	34.46
210.92	379.67	41.37	294.26	529.67	36.05
216.48	389.67	41.04			

Table XV-14-5

DENSITY OF SATURATED n-BUTANE VAPOR (Ref. 2)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
255.37	459.67	0.0901	310.93	559.67	0.552
258.15	464.67	0.100	313.71	564.67	0.588
260.93	469.67	0.112	316.48	569.67	0.633
263.71	474.67	0.124	319.26	574.67	0.676
266.48	479.67	0.138	322.04	579.67	0.730
269.26	484.67	0.153	324.82	584.67	0.783
272.04	489.67	0.169	327.59	589.67	0.840
274.82	494.67	0.186	330.37	594.67	0.900
277.59	499.67	0.205	333.15	599.67	0.965
280.37	504.67	0.224	335.93	604.67	1.035
283.15	509.67	0.246	338.70	609.67	1.115
285.93	514.67	0.268	341.48	614.67	1.190
288.71	519.67	0.294	344.26	619.67	1.275
291.48	524.67	0.321	347.04	624.67	1.365
294.26	529.67	0.347	349.82	629.67	1.455
297.04	534.67	0.377	352.59	634.67	1.557
299.82	539.67	0.407	355.37	639.67	1.660
302.59	544.67	0.439			
305.37	549.67	0.476			
308.15	554.67	0.510			

Table XV-14-6

SPECIFIC HEAT OF LIQUID n-BUTANE (Ref. 1, 2)

TEMPERATURE		SPECIFIC HEAT	TEMPERATURE		SPECIFIC HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
12	21.6	0.0065	180	324	0.4823
15	27	0.0134	190	342	0.4866
20	36	0.0186	200	360	0.4917
30	54	0.0740	210	378	0.4972
40	72	0.1129	220	396	0.5029
50	90	0.1480	230	414	0.5098
60	108	0.1770	240	432	0.5165
70	126	0.2037	250	450	0.5255
80	144	0.2288	260	468	0.5351
90	162	0.2514	270	486	0.5446
100	180	0.2743	272.66	490.68	Boiling Point
107.53	193.55	Transition	273	492	0.545
110	198	0.3412	278	500	0.554
120	216	0.3465	283	510	0.565
130	234	0.3551	289	520	0.576
134.87	247.77	Melting Point	294	530	0.587
140	252	0.4673	300	540	0.598
150	270	0.4732	305	550	0.609
160	288	0.4773			
170	306	0.4793			

(See Figure XV-14-4)

Table XV-14-7

SPECIFIC HEAT OF n-BUTANE GAS (Ref. 4)

TEMPERATURE		SPECIFIC HEAT
°K	°R	Btu/lb
255.37	459.67	0.3578
273.15	491.67	0.3751
283.15	509.67	0.3851
288.71	519.67	0.3908
310.93	559.67	0.4142
338.71	609.67	0.4441
366.48	659.67	0.4739
422.04	759.67	0.5316
477.19	859.67	0.5865
533.15	959.67	0.6374

(See Figure XV-14-5)

Table XV-14-8

HEAT OF VAPORIZATION OF n-BUTANE (Ref. 2)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
255.37	459.67	171.5	310.93	559.67	150.5
260.93	469.67	169.7	316.48	569.67	147.6
266.48	479.67	167.6	322.04	579.67	144.9
272.04	489.67	165.7	327.59	589.67	141.5
277.59	499.67	163.8	333.15	599.67	138.3
283.15	509.67	161.6	338.70	609.67	134.5
288.71	519.67	159.4	344.26	619.67	131.1
294.26	529.67	157.4	349.87	629.67	126.9
299.82	539.67	155.3	355.37	639.67	123.4
305.37	549.67	153.0			

(See Figure XV-14-6)

Table XV-14-9

VISCOSITY OF n-BUTANE (Ref. 2, 4)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centi-poises
183.15	329.67	0.63
193.15	347.67	0.536
203.15	365.67	0.462
213.15	383.67	0.403
223.15	401.67	0.355
233.15	419.67	0.315
243.15	437.67	0.282
253.15	455.67	0.253
263.15	473.67	0.229
273.15	491.67	0.210
277.59	499.67	0.200
288.71	519.67	0.180
299.82	539.67	0.162
310.93	559.67	0.147
322.04	579.67	0.131
333.15	599.67	0.116

(See Figure XV-14-7)

Table XV-14-10

VISCOSITY OF n-BUTANE
AT VARIOUS PRESSURES (Ref. 12)

TEMP. °F	100	130	160	190	220	250	280	340	400	460
PRESSURE psia	VISCOSITY – micropoises									
14.7	80	84	88	92	96	101	105	112	120	127
100	1415	1205	90	94	97	102	106	113	121	128
200	1430	1220	1050	885	101	103	107	114	122	129
300	1445	1235	1065	900	760	110	112	118	124	130
400	1460	1250	1078	915	775	615	122	124	128	132
500	1472	1265	1092	930	790	640	510	134	133	136
600	1485	1278	1105	945	805	665	535	152	142	142
700	1500	1293	1120	960	825	685	565	200	154	150
800	1512	1305	1135	975	840	705	590	294	166	158
1000	1540	1335	1160	1005	868	740	630	405	205	178
1500	1610	1400	1225	1075	940	820	715	530	360	255
2000	1675	1465	1290	1140	1005	887	785	610	462	350
3000	1795	1590	1412	1260	1125	1010	905	740	600	492
4000	1920	1705	1522	1375	1233	1120	1015	842	703	595
5000	2035	1820	1632	1480	1337	1222	1115	938	795	680
6000	2150	1930	1735	1580	1432	1315	1208	1025	875	760
7000	2270	2040	1838	1676	1528	1405	1293	1105	952	832
8000	2375	2150	1940	1772	1618	1495	1375	1180	1022	896
9000	2480	2260	2040	1865	1705	1580	1455	1253	1090	960
10000	2585	2370	2140	1960	1795	1665	1535	1325	1155	1020

Table XV-14-11

TOTAL ENTHALPY AND SPECIFIC VOLUME OF THE n-BUTANE SYSTEM
(Computed from data in References 1, 2, 4)

TEMP.	TOTAL ENTHALPY—Btu/lb			SPEC. VOL. VAPOR	TEMP.	TOTAL ENTHALPY—Btu/lb			SPEC. VOL. VAPOR
°R	Solid	Liquid	Vapor	ft^3/lb	°R	Solid	Liquid	Vapor	ft^3/lb
0	0				370				159.5
20	0.1				380		163.4	350.4	111.0
40	0.5				390				78.5
60	2.92				400		173.5	356.6	56.6
80	5.70				410				42.1
100	8.82				420		184.6	362.6	31.2
120	12.50				430				23.9
140	16.70				440		193.3	368.6	18.5
160	21.50				450				14.4
180	26.75				460		202.0	374.8	11.0
193.55	30.51				470			377.6	8.91
(transition)					480		210.4	380.6	7.18
193.55	45.81				490.8		217.7	383.5	5.65
200	47.80				500			386.0	4.85
210	51.00				510			389.2	4.05
220	54.5				520			392.3	3.38
230	58.10				530			395.5	2.88
242.77	62.95	97.44			540			398.6	2.44
250		101.7			550			401.7	2.12
260		106.0	(312.2)	1 240 000	560			404.7	1.81
270				278 000					
280		115.0	(318.8)	69 500	570			407.8	1.58
290				17 800	580			410.8	1.36
300		124.5	(325.0)	6 100	590			413.5	1.18
310				3 030	600			416.3	1.04
320		134.2	(331.6)	1 730					
330				1 025					
340		143.8	(338.0)	618					
350				380					
360		153.6	(344.2)	242					

(See Figure XV-14-11
Figure XV-14-12)

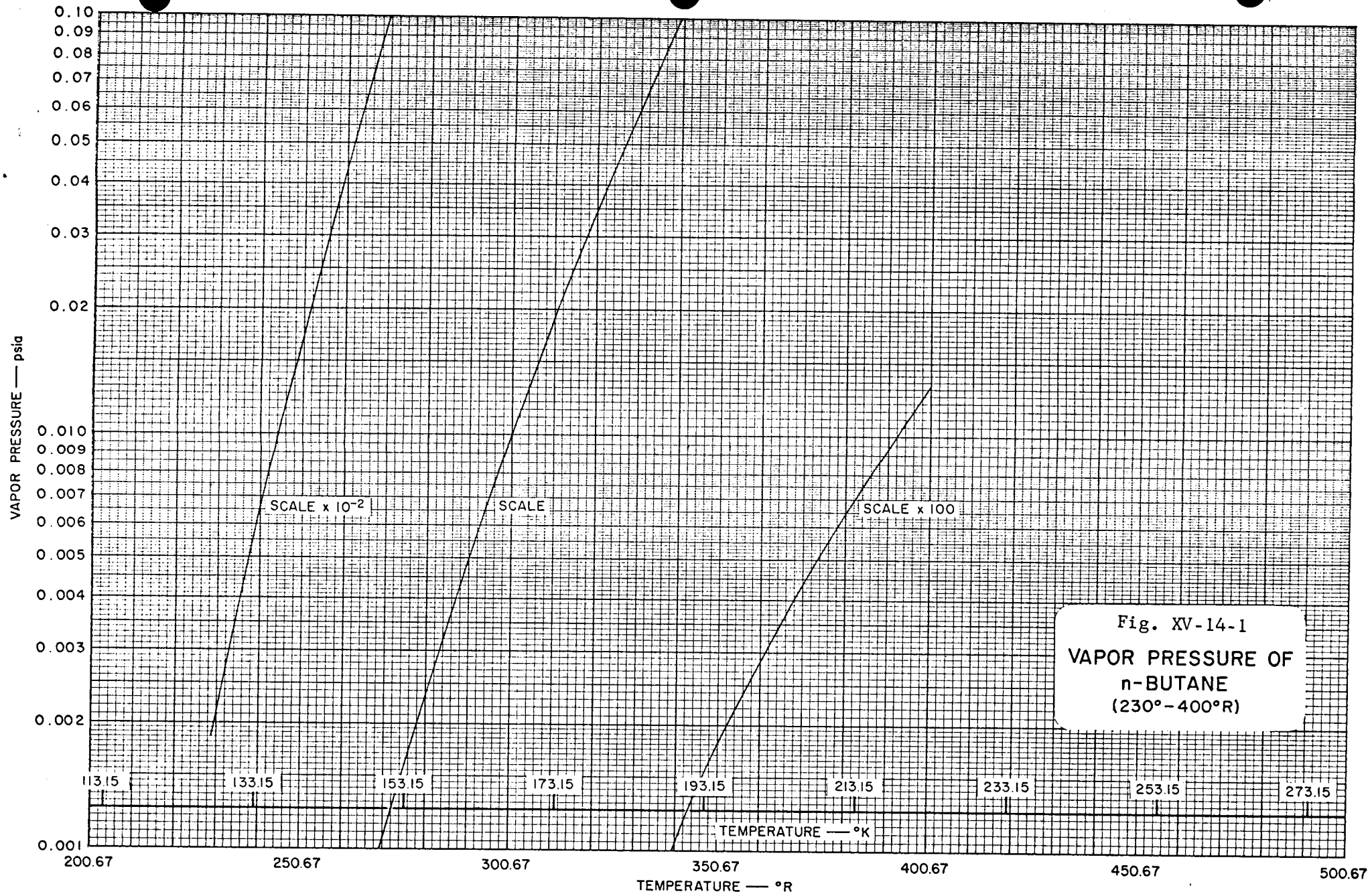


Fig. XV-14-1

VAPOR PRESSURE OF n-BUTANE (230°-400°R)

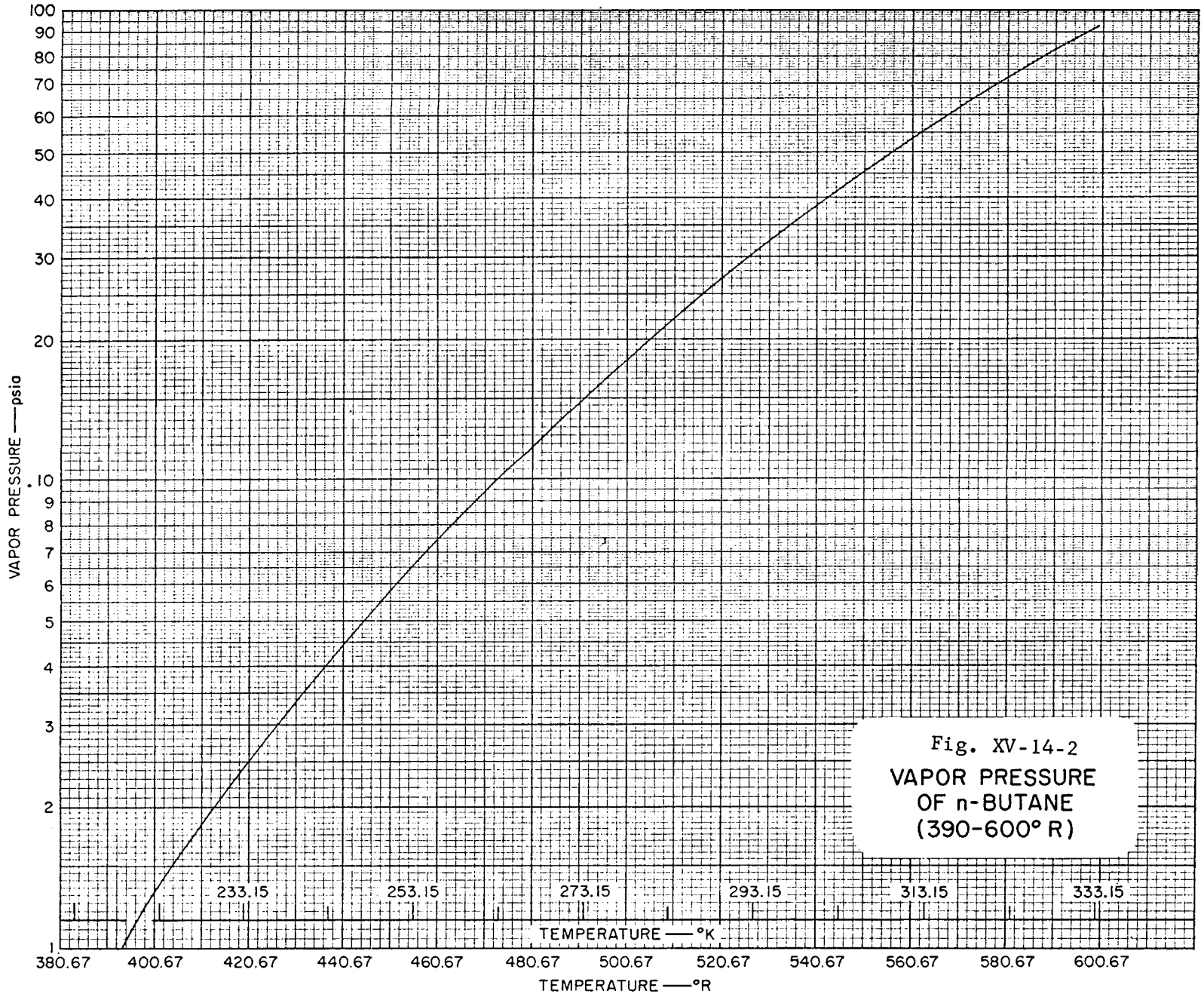
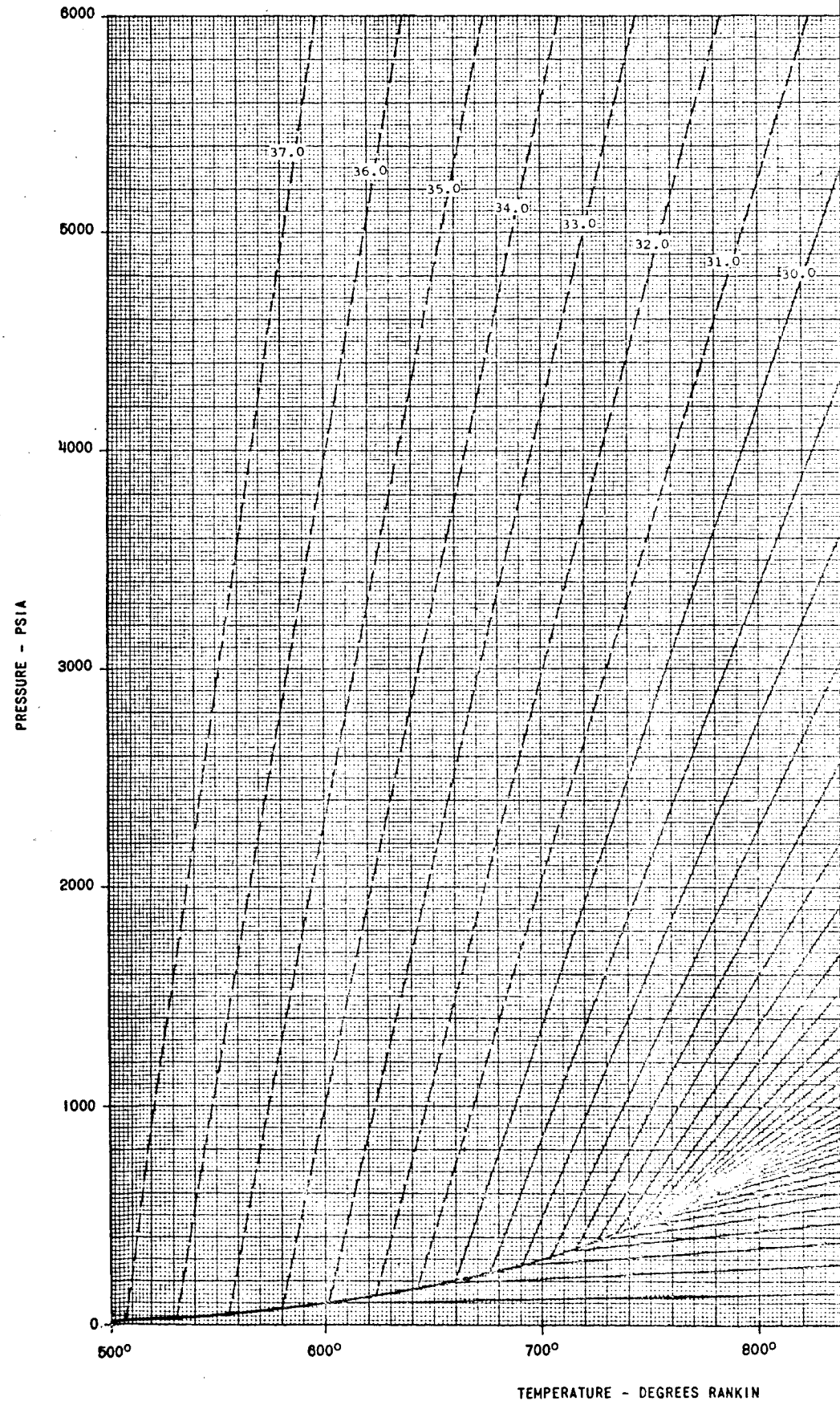


Fig. XV-14-2
VAPOR PRESSURE
OF n-BUTANE
(390-600° R)


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
37.0
36.0
35.0
34.0
33.0
32.0
31.0
30.0
500°
600°
700°
800°
TEMPERATURE - DEGREES RANKIN

XV-14-3-1

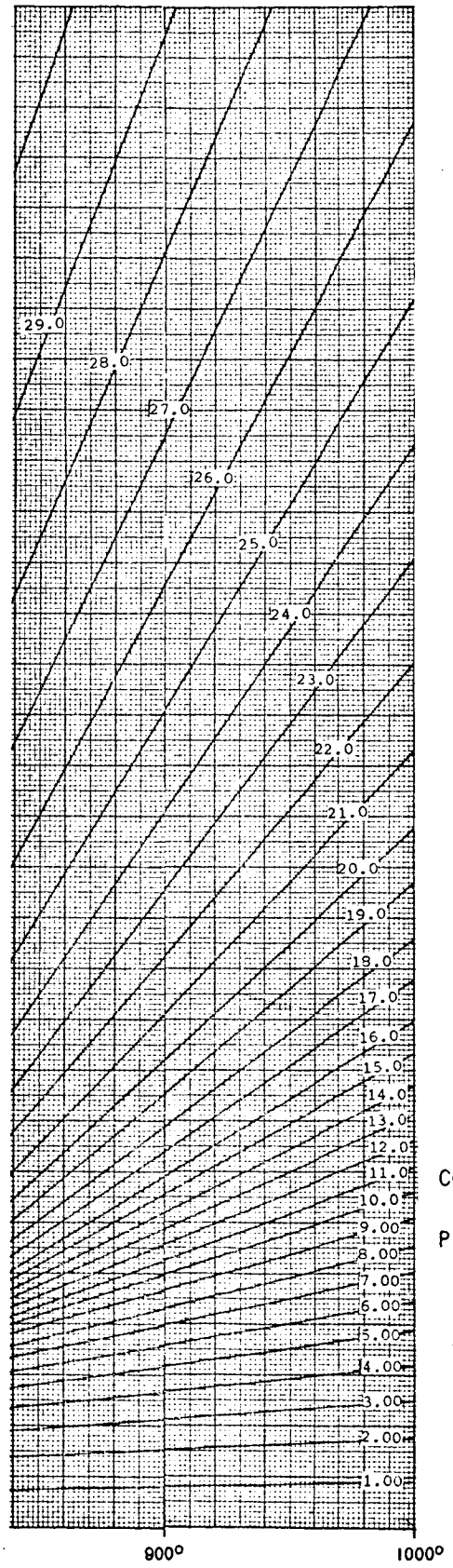


FIG. XV-14-3
BUTANE (C_4H_{10})

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

COMMONLY ACCEPTED
DATA

EXTRAPOLATED OR
UNCONFIRMED DATA

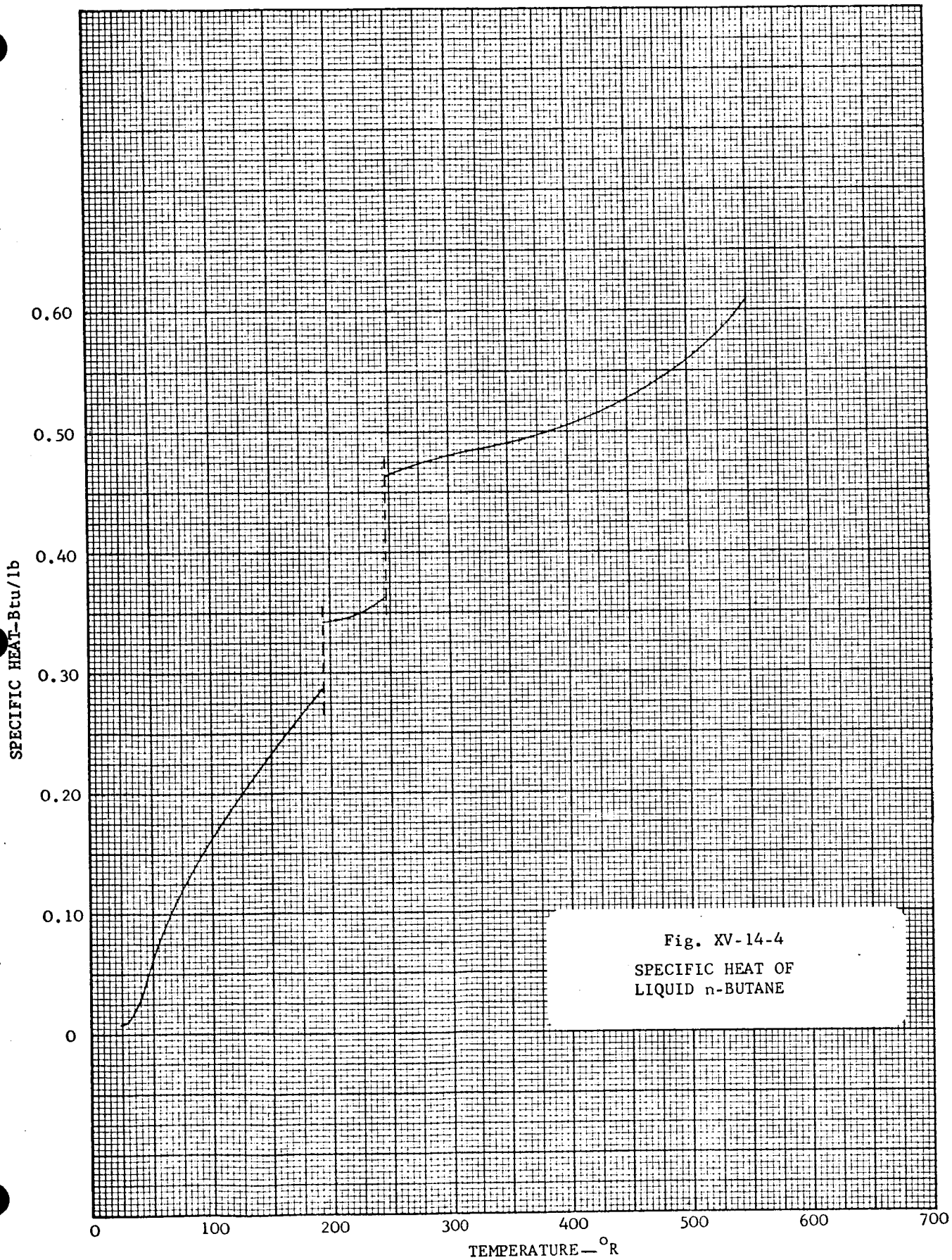


Fig. XV-14-4

SPECIFIC HEAT OF LIQUID n-BUTANE

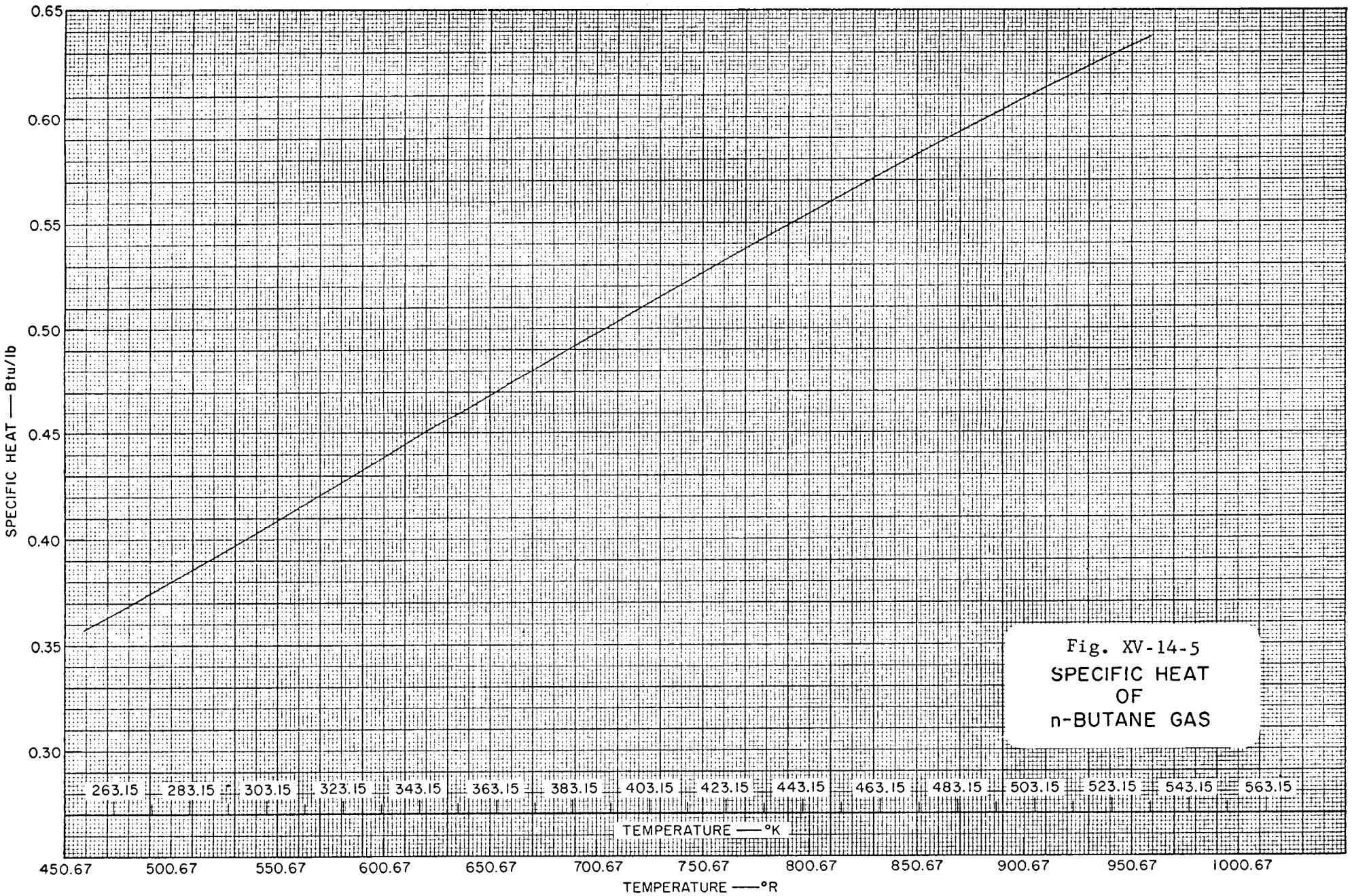


Fig. XV-14-5
SPECIFIC HEAT
OF
n-BUTANE GAS

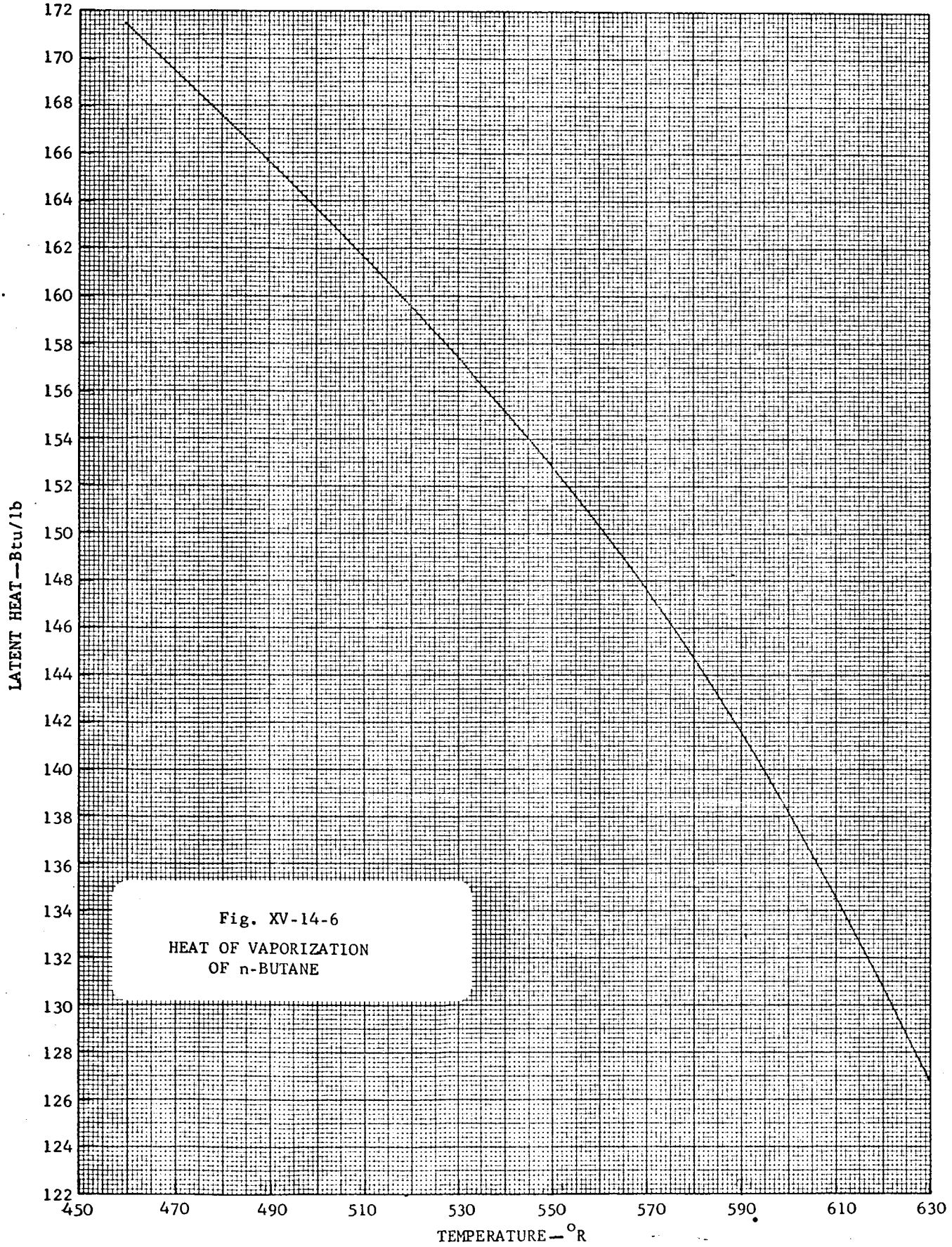


Fig. XV-14-6

HEAT OF VAPORIZATION
OF n-BUTANE

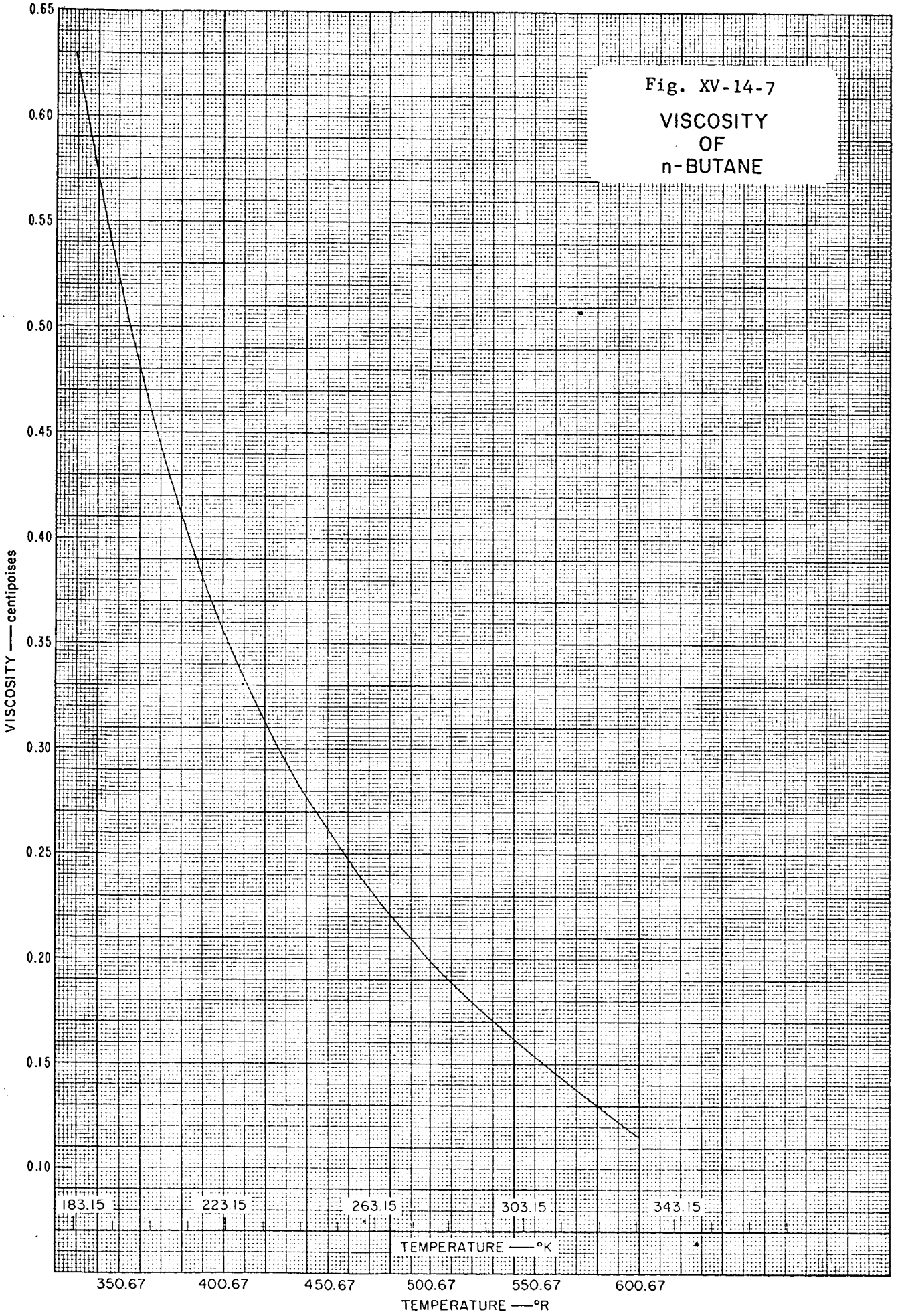


Fig. XV-14-7
VISCOSITY
OF
n-BUTANE
VISCOSITY — centipoises
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
183.15
223.15
263.15
303.15
343.15
TEMPERATURE — °K
350.67
400.67
450.67
500.67
550.67
600.67
TEMPERATURE — °R

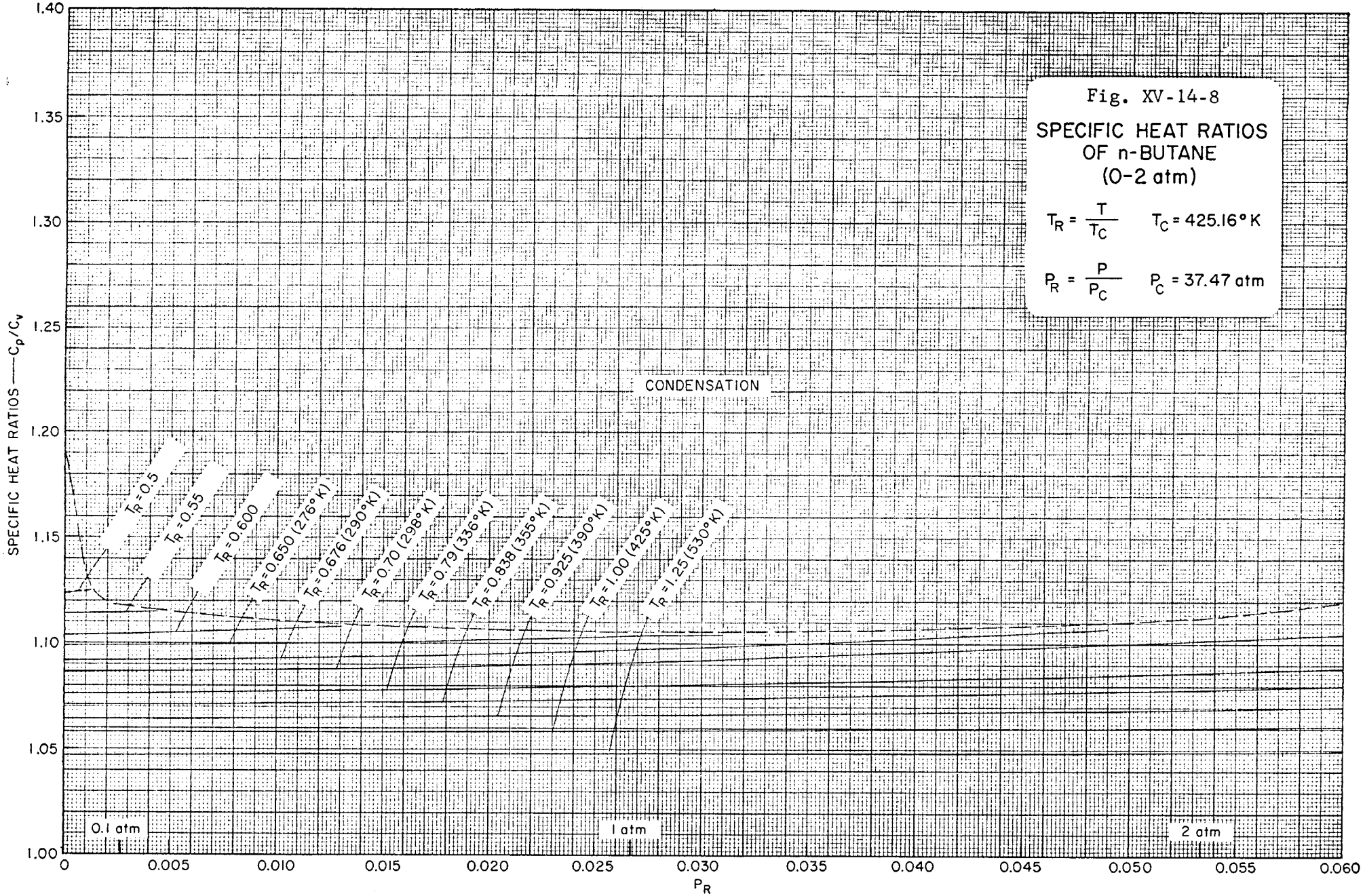


Fig. XV-14-8
SPECIFIC HEAT RATIOS OF n-BUTANE (0-2 atm)
$T_R = \frac{T}{T_C}$ $T_C = 425.16°K$
$P_R = \frac{P}{P_C}$ $P_C = 37.47$ atm
CONDENSATION
$T_R = 0.5$
$T_R = 0.55$
$T_R = 0.600$
$T_R = 0.650$ (276°K)
$T_R = 0.676$ (290°K)
$T_R = 0.70$ (298°K)
$T_R = 0.79$ (336°K)
$T_R = 0.838$ (355°K)
$T_R = 0.925$ (390°K)
$T_R = 1.00$ (425°K)
$T_R = 1.25$ (530°K)
0.1 atm
1 atm
2 atm
SPECIFIC HEAT RATIOS —— C_p/C_v
P_R
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050
0.055
0.060

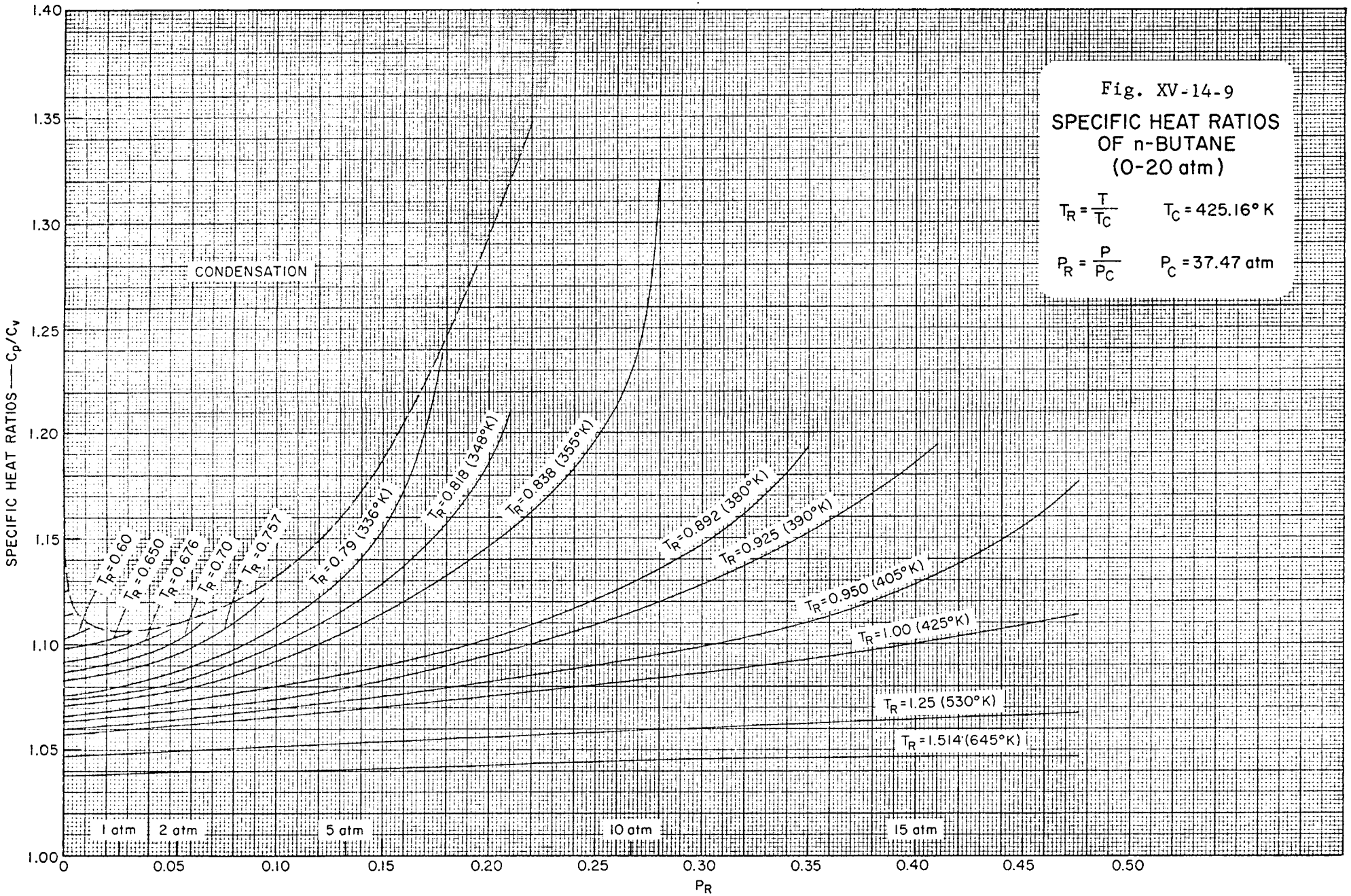


Fig. XV-14-9
SPECIFIC HEAT RATIOS OF n-BUTANE (0-20 atm)
$T_R = \frac{T}{T_C}$ $T_C = 425.16°$ K
$P_R = \frac{P}{P_C}$ $P_C = 37.47$ atm
CONDENSATION
$T_R = 0.60$
$T_R = 0.650$
$T_R = 0.676$
$T_R = 0.70$
$T_R = 0.757$
$T_R = 0.79$ (336°K)
$T_R = 0.818$ (348°K)
$T_R = 0.838$ (355°K)
$T_R = 0.892$ (380°K)
$T_R = 0.925$ (390°K)
$T_R = 0.950$ (405°K)
$T_R = 1.00$ (425°K)
$T_R = 1.25$ (530°K)
$T_R = 1.514$ (645°K)
1 atm
2 atm
5 atm
10 atm
15 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

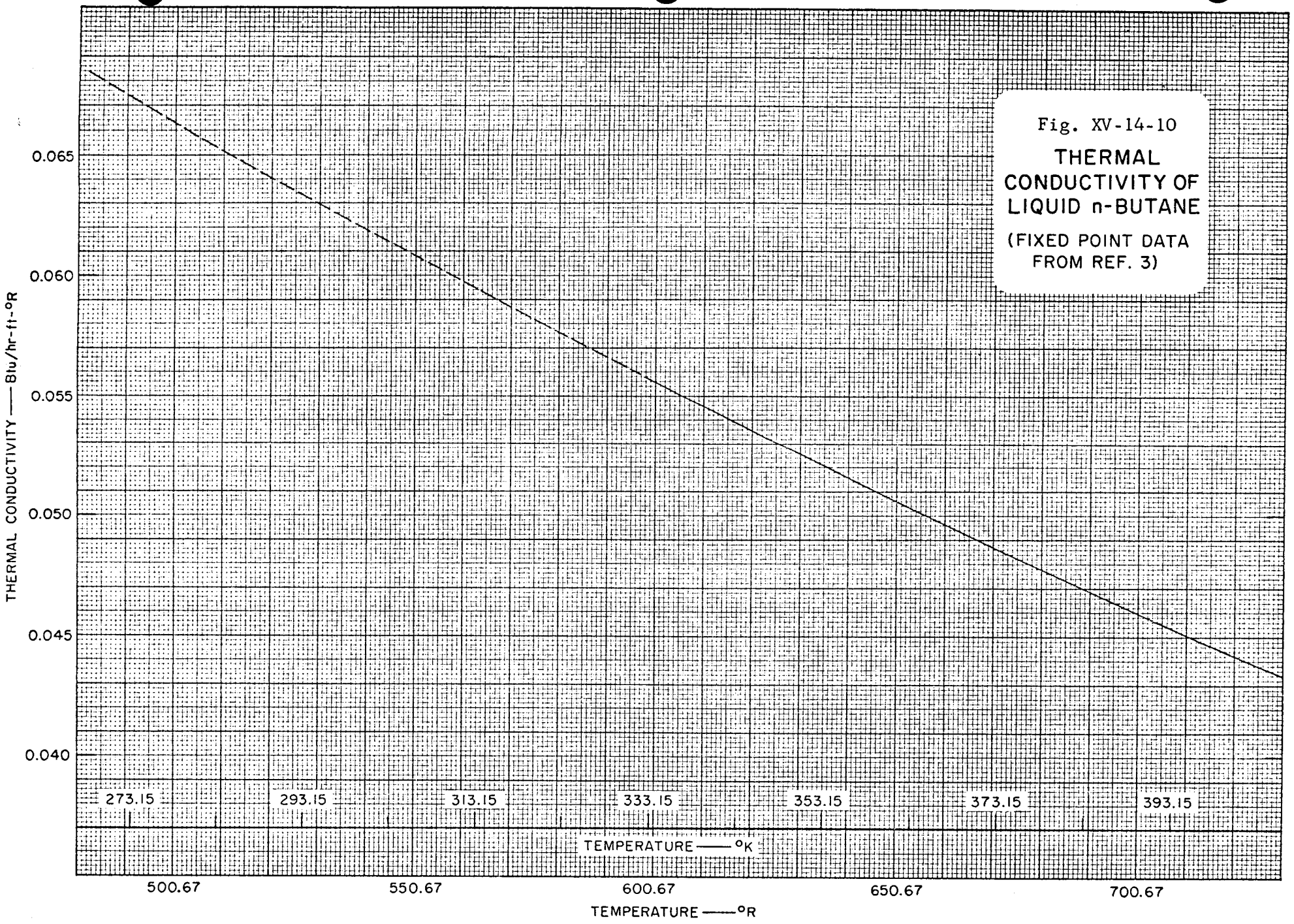


Fig. XV-14-10

THERMAL CONDUCTIVITY OF LIQUID n-BUTANE

(FIXED POINT DATA FROM REF. 3)

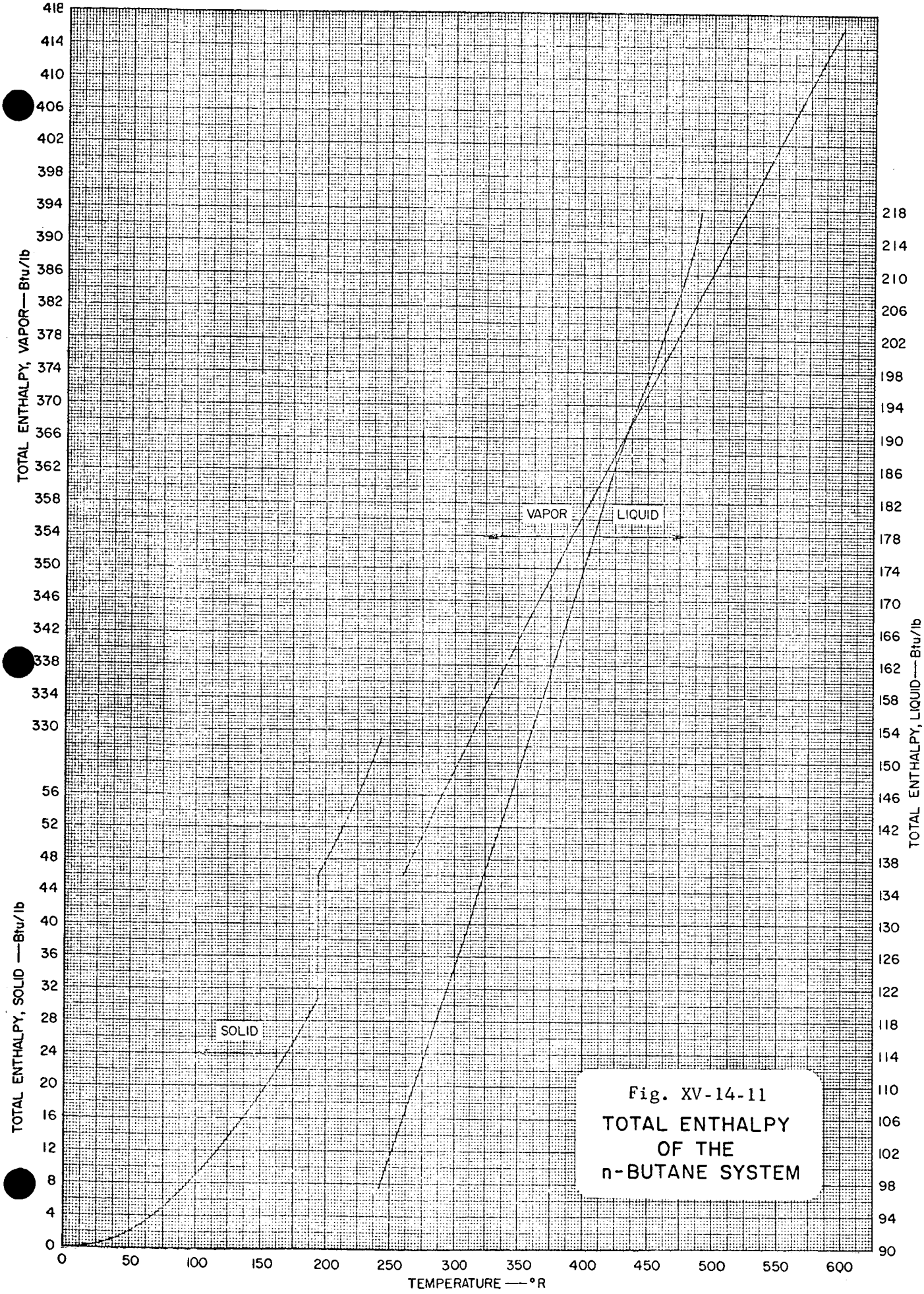


Fig. XV-14-11

TOTAL ENTHALPY OF THE n-BUTANE SYSTEM

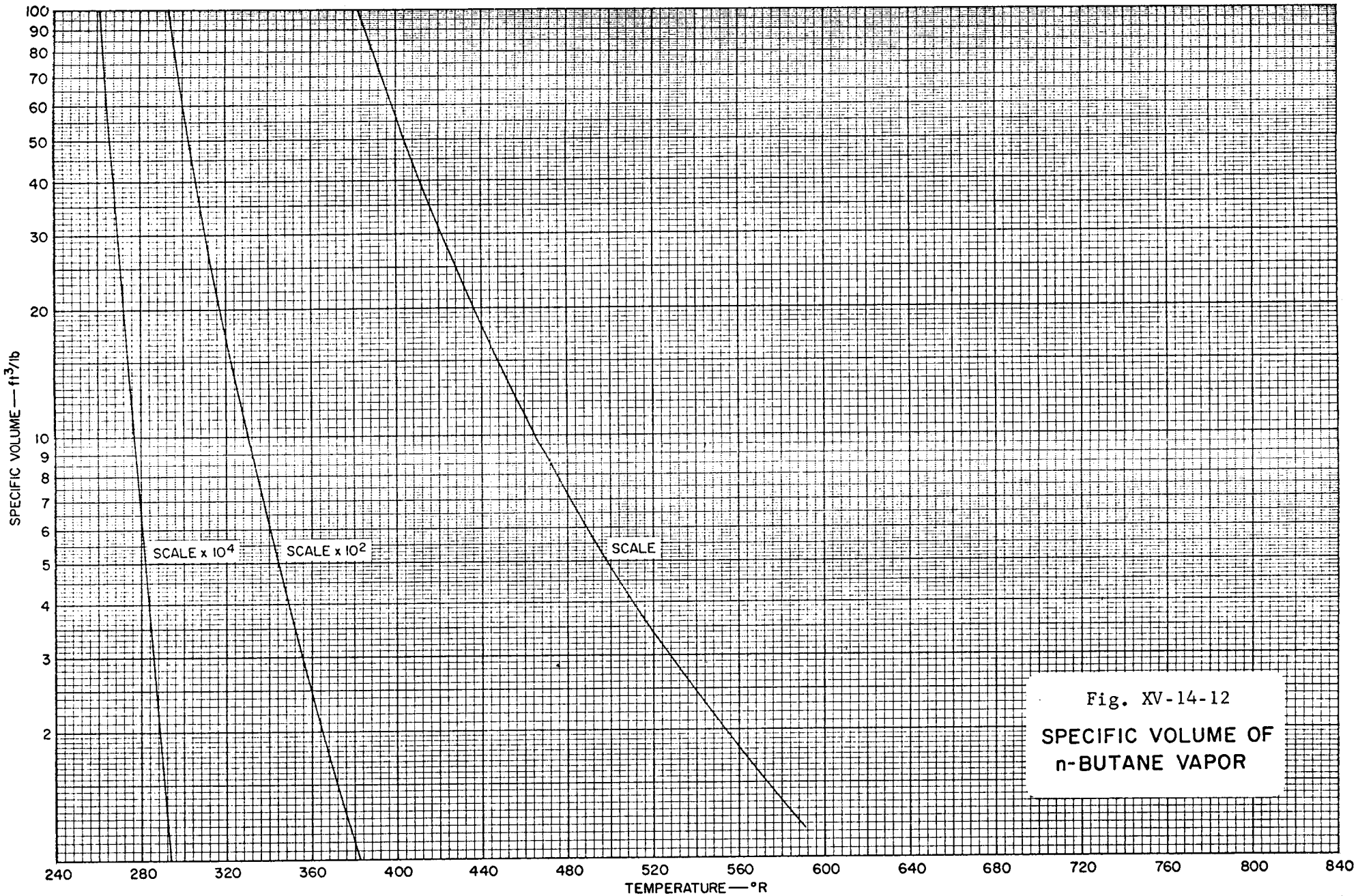


Fig. XV-14-12

SPECIFIC VOLUME OF n-BUTANE VAPOR

XV-14 n-BUTANE REFERENCES

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11. Kay, W.B. Ind. Eng. Chem. 32, 358-60, 1940.
12. Dolan, J.P., et al. (Inst. Gas Technol., Chicago, Ill.) Liquid, gas and dense fluid viscosity of n-Butane. J. Chem. and Eng. Data 8, no. 3, 396-9, July 1963.

Table XV-15-1

PHYSICAL CONSTANTS

OF

AMMONIA

		REF.
Molecular Weight	17.03	1
Boiling Point @ 1 atm.	-28.0°F	1
Freezing Point @ 1 atm.	-107.9°F	1
Specific Volume @ 70°F, 1 atm.	22.6 cu-ft/lb	1
Vapor Pressure @ 70°F (cylinder pressure)	128.8 psia	1
Specific Gravity, (Air = 1)	0.5870	1
Density		
Liquid @ b.p.	42.08 lb/cu-ft	1
Gas @ b.p.	0.0556 lb/cu-ft	1
Critical Temperature	271.2°F	1
Critical Pressure	1636 psia	1
Critical Density	14.671 lb/cu-ft	1
Latent Heat of Vaporization @ b.p.	589.4 Btu/lb	1
Latent Heat of Fusion @ m.p.	194.6 Btu/lb	9
Specific Heat of Gas		
c_p @ 59°F, 1 atm.	0.5232 Btu/lb-°F	1
c_v @ 59°F, 1 atm.	0.3995 Btu/lb-°F	1
Specific Heat Ratio, c_p/c_v	1.31	1
Thermal Conductivity @ 32°F, 1 atm.	0.0128 Btu/hr-ft-°F	1
Viscosity		
Liquid @ 92.3°F	1.79×10^{-4} lb/ft-sec	1
Gas @ 32°F	6.17×10^{-6} lb/ft-sec	1
Solubility in Water @ 32°F, 1 atm.	47.3% by weight	1
Surface Tension @ 52°F	0.001603 lb/ft	8

Table XV-15-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR AMMONIA

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	4.81836	4.97846	3661.96	70.8109
$mole/cm^3$	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0771820	0.0797463	58.6584	1.13427
$lb/mole/ft^3$	1.31441	1.35808	998.952	19.3166

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.67687	2.76581	2034.42	39.3394
$mole/cm^3$	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0428789	0.0443035	32.5880	0.630147
$lb/mole/ft^3$	0.730228	0.754489	554.973	10.7314

Table XV-15-2

VAPOR PRESSURE OF LIQUID AMMONIA

(Ref. 4)

TEMPERATURE		VAPOR PRESSURE	
°K	°R	atm	psia
195.15	351.27	0.0582	0.857
205.15	369.27	0.1246	1.831
215.15	387.27	0.2461	3.617
225.15	405.27	0.4536	6.666
235.15	423.27	0.7875	11.573
245.15	441.27	1.2992	19.093
255.15	459.27	2.0499	30.125
265.15	477.27	3.1112	45.722
275.15	495.27	4.5640	67.073
285.15	513.27	6.4985	95.502
295.15	531.27	9.0125	132.448
305.15	549.27	12.212	179.47
315.15	567.27	16.209	238.21
325.15	585.27	21.121	310.39
335.15	603.27	27.079	397.95
345.15	621.27	34.227	503.00
355.15	639.27	42.712	627.70
365.15	657.27	52.677	774.14
375.15	675.27	64.274	944.57
385.15	693.27	77.668	1141.4
395.15	711.27	93.045	1367.4
405.15	729.27	110.613	1625.6
405.9	730.62	112.3 (c.p.)	1650.4

(See Figure XV-15-1)

Table XV-15-3

VAPOR PRESSURE OF SOLID AMMONIA

TEMPERATURE		VAPOR PRESSURE		REF.
°F	°R	psia	atm	
-197.3	262.28	0.00147	0.000100	13
-180.6	278.98	0.00553	0.000376	13
-168.3	291.28	0.01300	0.000884	13
-167.39	292.19	0.01837	0.001250	14
-159.5	300.08	0.02375	0.001616	13
-154.61	304.97	0.04602	0.003132	14
-148.29	311.29	0.07309	0.004974	12
-144.69	314.89	0.09379	0.006382	12
-135.69	323.89	0.16978	0.011553	12
-126.69	332.89	0.29818	0.020290	12
-117.69	341.89	0.50798	0.034566	12
-108.69	350.89	0.84251	0.057329	12

(See Figure XV-15-2)

Table XV-15-4

DENSITY OF SATURATED AMMONIA VAPOR
(Ref. 4, 7)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
198.15	356.67	0.00488	303.15	545.67	0.564
203.15	365.67	0.00696	313.15	563.67	0.750
213.15	383.67	0.0133	323.15	582.67	0.984
223.15	401.67	0.0238	333.15	599.67	1.279
233.15	419.67	0.0403	343.15	617.67	1.656
243.15	437.67	0.0648	353.15	635.67	2.131
253.15	455.67	0.100	363.15	653.67	2.738
263.15	473.67	0.149	373.15	671.67	3.547
273.15	491.67	0.216	406.05	730.9	14.576 (c.p.)
283.15	509.67	0.303			
293.15	527.67	0.417			

Table XV-15-5

DENSITY OF LIQUID AMMONIA (Ref. 4, 7)

TEMPERATURE		DENSITY	TEMPERATURE		DENSITY
°K	°R	lb/ft³	°K	°R	lb/ft³
198.15	356.67	45.63	293.15	527.67	38.10
203.15	365.67	45.28	303.15	545.67	37.16
213.15	383.67	44.56	313.15	563.67	36.18
223.15	401.67	43.83	323.15	582.67	35.14
233.15	419.67	43.08	333.15	599.67	34.04
243.15	437.67	42.31	343.15	617.67	32.86
253.15	455.67	41.52	353.15	635.67	31.57
263.15	473.67	40.70	363.15	653.67	30.15
273.15	491.67	39.87	373.15	671.67	28.53
283.15	509.67	39.00	406.05	730.9	14.58 (c.p.)

Table XV-15-6

DENSITY OF AMMONIA (Ref. 27, 28, 29)

DENSITY-lb/ft^3							
PRESS. psia / TEMP. °R	500	1000	2000	3000	4000	5000	6000
500	39.65	39.80					
550	36.54	36.91	37.27	37.67	38.05	38.40	38.75
600	34.20	34.50	35.14	35.70	36.19	36.60	37.00
650	1.49	30.10	31.29	32.20	32.95	33.60	34.21
700	1.29	3.45	28.00	29.34	30.40	31.32	32.06
750	1.05	2.70	11.60	23.20	25.88	27.40	28.54
800		2.44	6.60	16.62	21.87	24.40	26.00
850		2.09	5.00	10.10	16.20	19.60	22.08

(See Figure XV-15-3)

Table XV-15-7

SURFACE TENSION OF LIQUID AMMONIA
(Ref. 10, 11)

TEMPERATURE		SURFACE TENSION
°F	°R	lb/ft
-68.8	390.78	0.002683
-61.1	398.48	0.002624
-38.2	421.38	0.002437
-29.2	430.38	0.002357
-27.4	432.18	0.002334
52.0	511.58	0.001602
93.29	552.87	0.001237
138.16	597.74	0.000887

(See Figure XV-15-4)

Table XV-15-8

VISCOSITY OF LIQUID AMMONIA
(Saturated)

TEMPERATURE		VISCOSITY	REF.
°F	°R	lb/ft-sec	
-58.0	401.58	0.000213	16
-40.0	419.58	0.000186	16
-28.3	431.28	0.000171	16
- 4.0	455.58	0.000170	17
14.0	473.58	0.000165	17
32.0	491.58	0.000161	17
50.0	509.58	0.000155	17
68.0	527.58	0.000147	17
70.0	529.58	0.000107	15
100.0	559.58	0.000088	15
130.0	589.58	0.000069	15
160.0	619.58	0.000050	15
190.0	649.58	0.000033	15
220.0	679.58	0.000016	15

Table XV-15-9

VISCOSITY OF LIQUID AMMONIA (Ref. 15)

PRESSURE	VISCOSITY — centipoise						
psia	40°F (73.32)*	70°F (128.8)*	100°F (211.9)*	130°F (330.3)*	160°F (492.8)*	190°F (708.9)*	220°F (989.5)*
Bubble point	0.1880	0.1592	0.1306	0.1028	0.0748	0.0488	0.0240
200	0.1884	0.1595					
400	0.1892	0.1603	0.1316	0.1030			
600	0.1898	0.1611	0.1324	0.1038	0.0754		
800	0.1905	0.1618	0.1332	0.1044	0.0762	0.0492	
1000	0.1911	0.1624	0.1338	0.1051	0.0772	0.0503	0.0243
1500	0.1924	0.1641	0.1362	0.1070	0.0795	0.0527	0.0274
2000	0.1940	0.1656	0.1367	0.1088	0.0822	0.0551	0.0304
2500	0.1954	0.1670	0.1380	0.1108	0.0846	0.0576	0.0330
3000	0.1972	0.1684	0.1395	0.1127	0.0870	0.0600	0.0355
3500	0.1987	0.1697	0.1410	0.1145	0.0890	0.0625	0.0362
4000	0.3004	0.1712	0.1427	0.1163	0.0910	0.0650	0.0390
5000			0.1460	0.1201	0.0654	0.0700	0.0429
6000					0.1000	0.0750	0.0468

*Numbers in parentheses are the bubble point pressures in psia.

Table XV-15-10

VISCOSITY OF GASEOUS AMMONIA
(Ref. 18)

TEMPERATURE		VISCOSITY
^{o}F	^{o}R	lb/ft-sec
68.0	527.58	6.630×10^{-6}
104.0	563.58	7.151×10^{-6}
140.0	599.48	7.661×10^{-6}
176.0	635.58	8.178×10^{-6}
208.4	667.98	8.608×10^{-6}

Table XV-15-11

VISCOSITY OF GASEOUS AMMONIA

AT CONSTANT TEMPERATURE
(Ref. 19)

PRESSURE	VISCOSITY AT 176°F
psia	lb/ft-sec
147	8.165×10^{-6}
294	8.232×10^{-6}
441	8.366×10^{-6}

Table XV-15-12

HEAT CAPACITIES OF SOLID AND LIQUID AMMONIA (Ref. 6)

TEMPERATURE		HEAT CAPACITY	TEMPERATURE		HEAT CAPACITY
^{o}K	^{o}R	Btu/lb-^{o}R	^{o}K	^{o}R	Btu/lb-^{o}R
20	36	0.0216	170	306	0.6119
30	54	0.0607	180	324	0.6476
40	72	0.1081	190	342	0.6876
50	90	0.1564	195.41	351.74	M.P.
60	108	0.2040	200	360	1.032
70	126	0.2485	210	378	1.042
80	144	0.2909	220	396	1.051
90	162	0.3295	230	414	1.059
100	180	0.3667	239.73	431.51	B.P.
110	198	0.4038	240	432	1.064
120	216	0.4402			
130	234	0.4757			
140	252	0.5108			
150	270	0.5444			
160	288	0.5782			

(See Figure XV-15-5)

Table XV-15-13

HEAT CAPACITY OF AMMONIA GAS
(Btu/lb-°F) (Ref. 2)

TEMPERATURE		PRESSURE IN ATMOSPHERES		
°K	°R	1	10	20
243.15	437.67	0.5513		
253.15	455.67	0.5344		
263.15	473.67	0.5247		
273.15	491.67	0.5194		
283.15	509.67	0.5168		
293.15	527.67	0.5161		
303.15	545.67	0.5167	0.7289	
312.15	563.67	0.5181	0.6826	
323.15	581.67	0.5201	0.6510	0.9173
333.15	599.67	0.5227	0.6290	0.8244
343.15	617.67	0.5256	0.6136	0.7621
353.15	635.67	0.5288	0.6029	0.7192
363.15	653.67	0.5323	0.5955	0.6890
373.15	671.67	0.5359	0.5905	0.6674
383.15	689.67	0.5397	0.5874	0.6518
393.15	707.67	0.5437	0.5856	0.6404
403.15	725.67	0.5478	0.5850	0.6322
413.15	743.67	0.5520	0.5852	0.6263
423.15	761.67	0.5563	0.5860	0.6223

(See Figure XV-15-6)

Table XV-15-14

HEAT OF VAPORIZATION OF AMMONIA (Ref. 7)

TEMPERATURE		LATENT HEAT	TEMPERATURE		LATENT HEAT
°K	°R	Btu/lb	°K	°R	Btu/lb
238.7	429.7	590.7	294.3	529.7	508.6
244.3	439.7	583.6	299.8	539.7	498.7
249.8	449.7	576.4	305.4	549.7	488.5
255.4	459.7	568.9	310.9	559.7	477.8
260.9	469.7	561.1	316.5	569.7	466.7
266.5	479.7	553.1	322.0	579.7	455.0
272.0	489.7	544.8	324.8	584.7	448.9
277.6	499.7	536.2			
283.2	509.7	527.3			
288.7	519.7	518.1			

(See Figure XV-15-9)

Table XV-15-15

THERMAL CONDUCTIVITY OF GASEOUS AMMONIA
AT ATMOSPHERIC PRESSURE

TEMPERATURE		THERMAL CONDUCTIVITY	REF.
°F	°R	Btu/hr-ft-°F	
-71.7	387.88	0.00924	21
-33.0	426.58	0.01067	21
32	491.58	0.01243	21
122	581.58	0.016	20
212	671.58	0.018	20
260	719.58	0.0210	22
350	809.58	0.0250	22
440	899.58	0.0288	22
530	989.58	0.0328	22
620	1079.58	0.0361	22

Table XV-15-16

THERMAL CONDUCTIVITY OF GASEOUS AMMONIA
AS FUNCTION OF TEMPERATURE (Ref. 23)

TEMPERATURE	PRESSURE	THERMAL CONDUCTIVITY
°R	atm	Btu/hr-ft-°F
581.58	0.0	0.0156
581.58	5.3	0.0163
581.58	8.5	0.0168
761.58	0.0	0.0234
761.58	4.9	0.0238
761.58	9.0	0.0245
941.58	0.0	0.0332
941.58	5.4	0.0335
941.58	9.0	0.0340

Table XV-15-17

TOTAL ENTHALPY AND SPECIFIC VOLUME
OF THE AMMONIA SYSTEM

(Computed from data in References 4, 6)

TEMPERATURE	TOTAL ENTHALPY-Btu/lb			SPEC. VOL. VAPOR
^{o}R	Solid	Liquid	Vapor	ft^3/lb
0	0			
50	0.723			
100	6.56			
150	18.93			
200	36.78			
250	59.69			
300	87.38			
351.65	120.15	263.0	903.6	251.3
360		271.6	907.2	180.1
380		292.4	915.7	85.82
400		313.3	923.9	44.28
420		334.5	931.9	24.64
431.42		346.6	936.1	18.12
440		355.8	939.2	14.63
460		377.5	946.1	9.048
480		399.1	951.9	5.870
500		421.2	957.1	3.946
520		443.6	961.4	2.735
540		466.6	964.0	1.944
560		489.8	967.2	1.412
580		513.5	968.1	1.042

(See Figure XV-15-12
Figure XV-15-13)

Table XV-15-18

LOW FREQUENCY VELOCITY OF SOUND
IN GASEOUS AMMONIA

TEMPERATURE	PRESSURE	VELOCITY	REF.
^{o}R	atm	ft/sec	
435.78	0.992	1306	25
435.78	0.843	1310	25
435.78	0.601	1313	25
435.78	0.425	1317	25
435.78	0.263	1318	25
457.38	0.942	1323	25
457.38	0.737	1327	25
457.38	0.647	1327	25
457.38	0.414	1330	25
457.38	0.263	1334	25
475.38	0.921	1338	25
491.58	0.947	1361	25
521.28	1	1389	24
542.68	0.967	1418	25
565.38	1	1446	24
605.88	1	1496	24
646.38	1	1543	24

Table XV-15-19

LOW FREQUENCY VELOCITY OF SOUND
IN LIQUID AMMONIA (Ref. 26)

TEMPERATURE	PRESSURE	VELOCITY
^{o}R	psia	ft/sec
524.58	615	4570
594.58	615	3800
631.58	615	3020

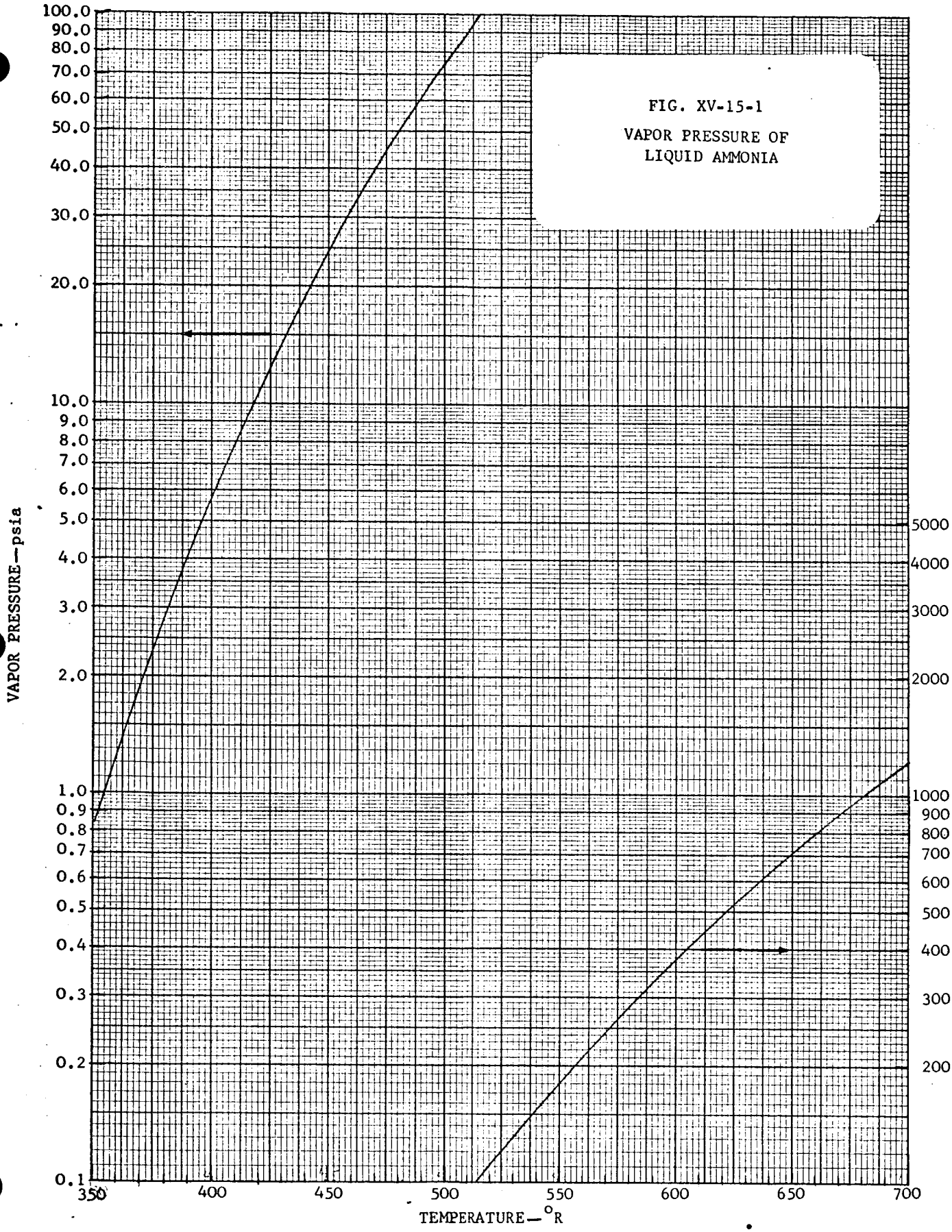

FIG. XV-15-1

VAPOR PRESSURE OF LIQUID AMMONIA

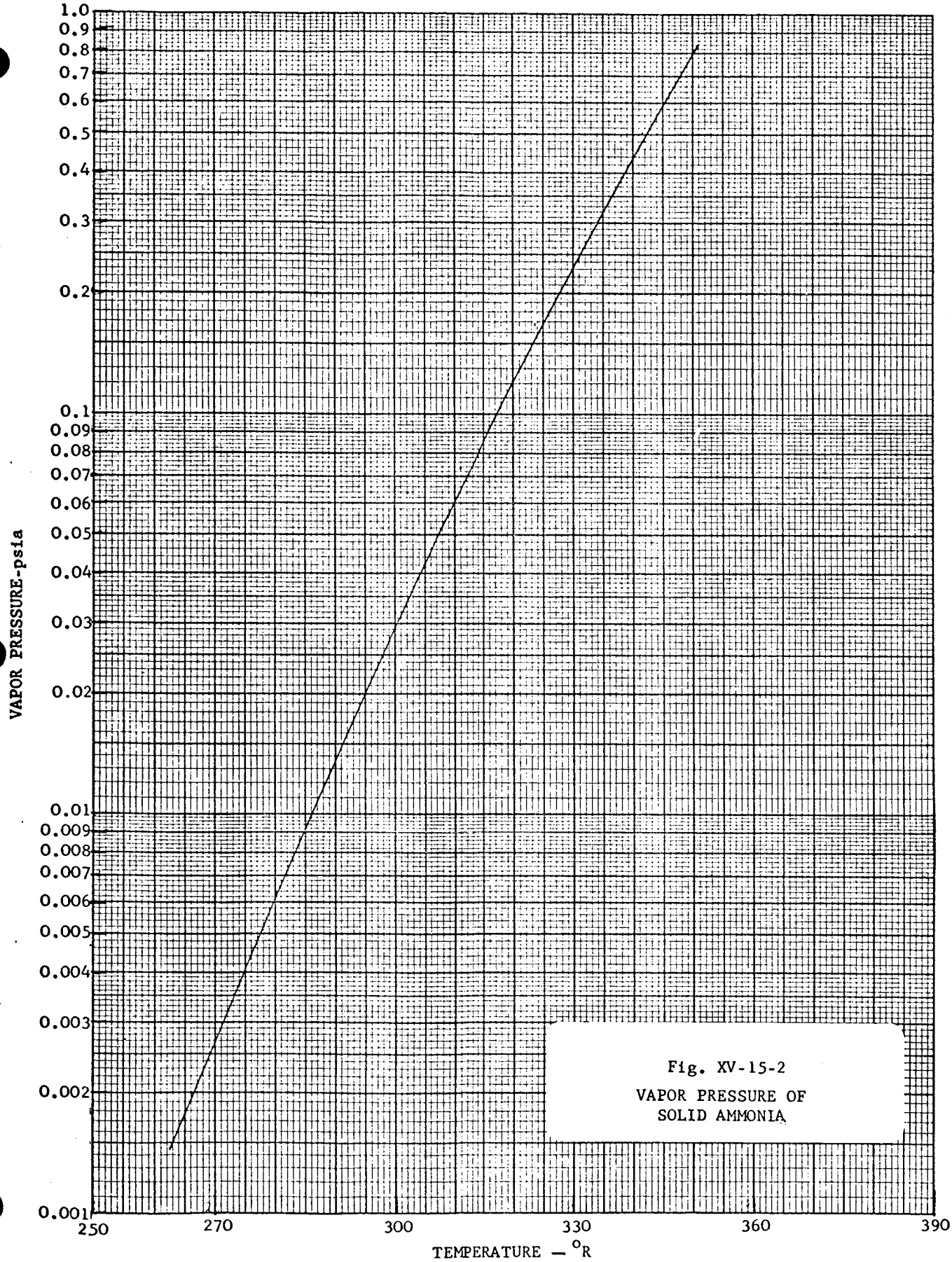

Fig. XV-15-2
VAPOR PRESSURE OF
SOLID AMMONIA

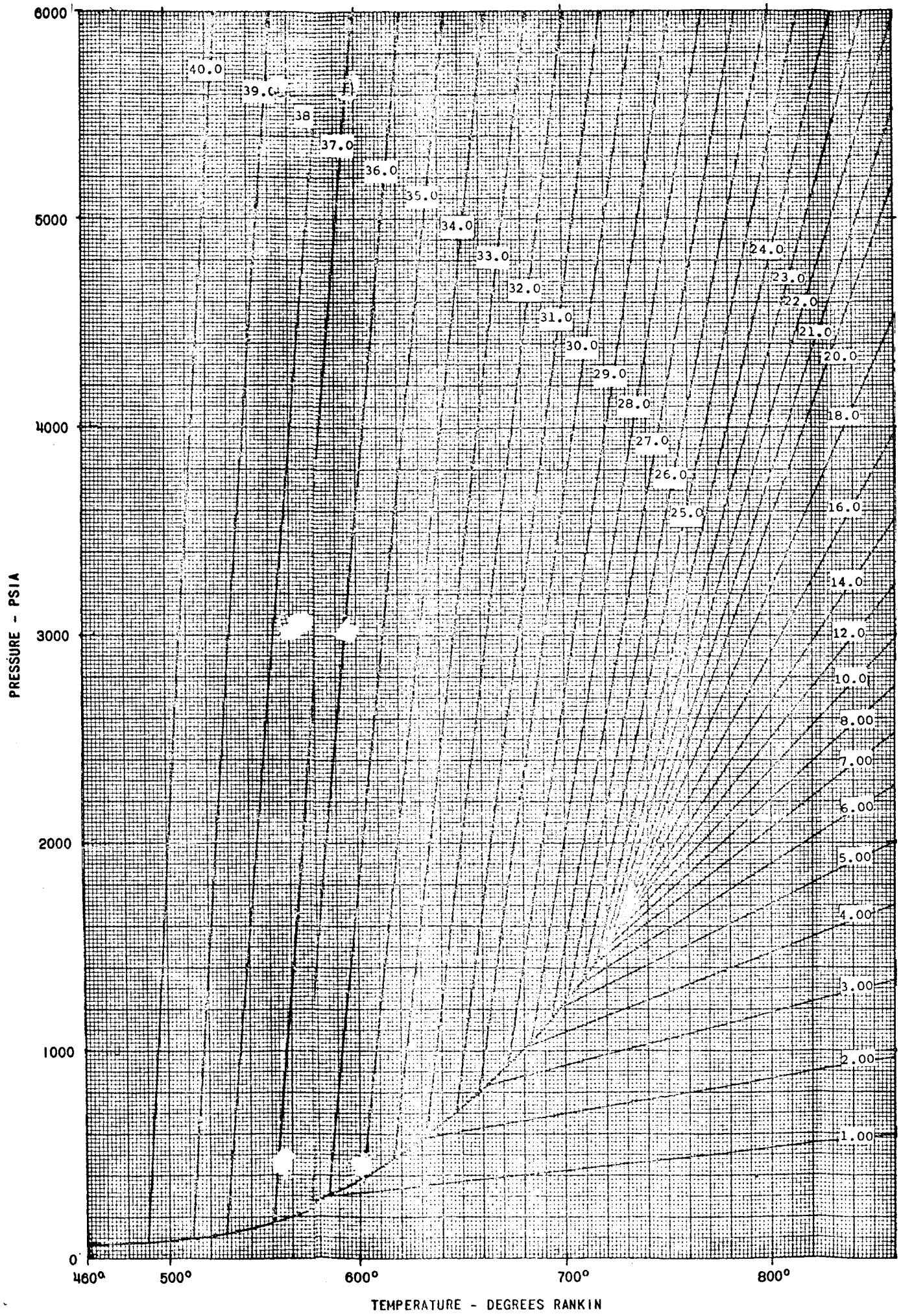

FIG. XV-15-3-2
AMMONIA (NH_3)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

XV-15-3-1

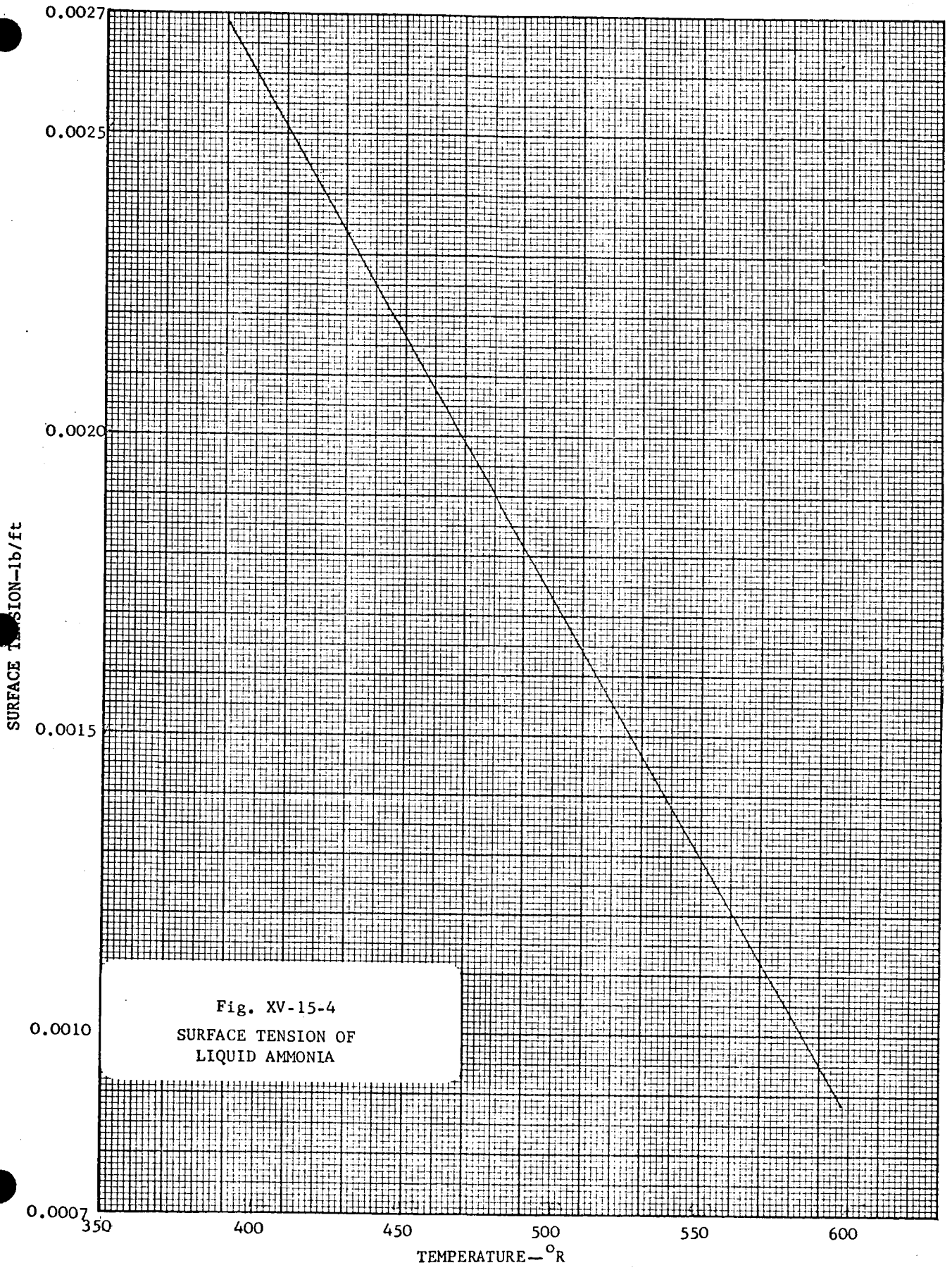

Fig. XV-15-4
SURFACE TENSION OF
LIQUID AMMONIA

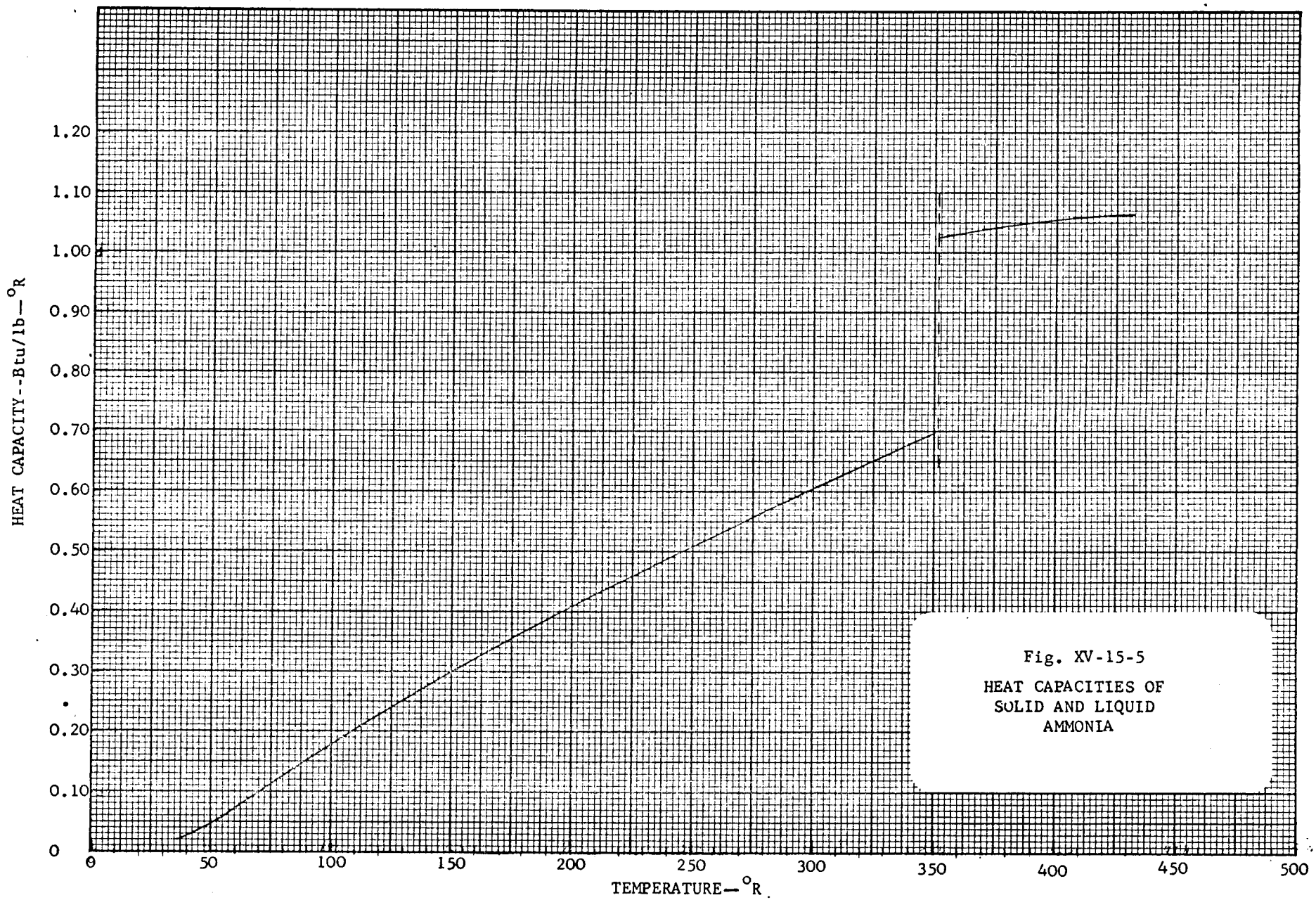

Fig. XV-15-5

HEAT CAPACITIES OF SOLID AND LIQUID AMMONIA

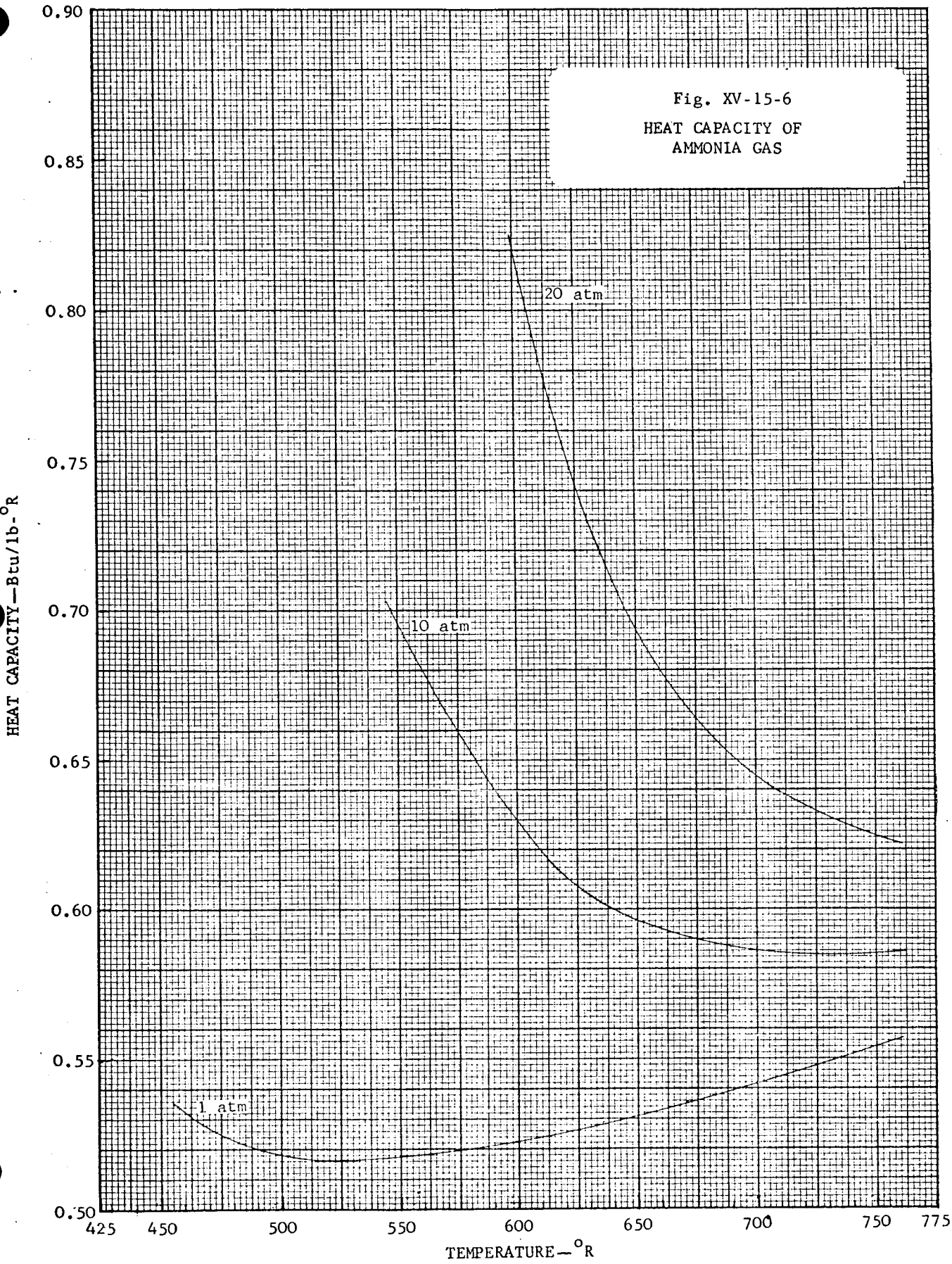
Fig. XV-15-6
HEAT CAPACITY OF
AMMONIA GAS
20 atm
10 atm
1 atm
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
HEAT CAPACITY—Btu/lb-°R
425
450
500
550
600
650
700
750
775
TEMPERATURE—°R

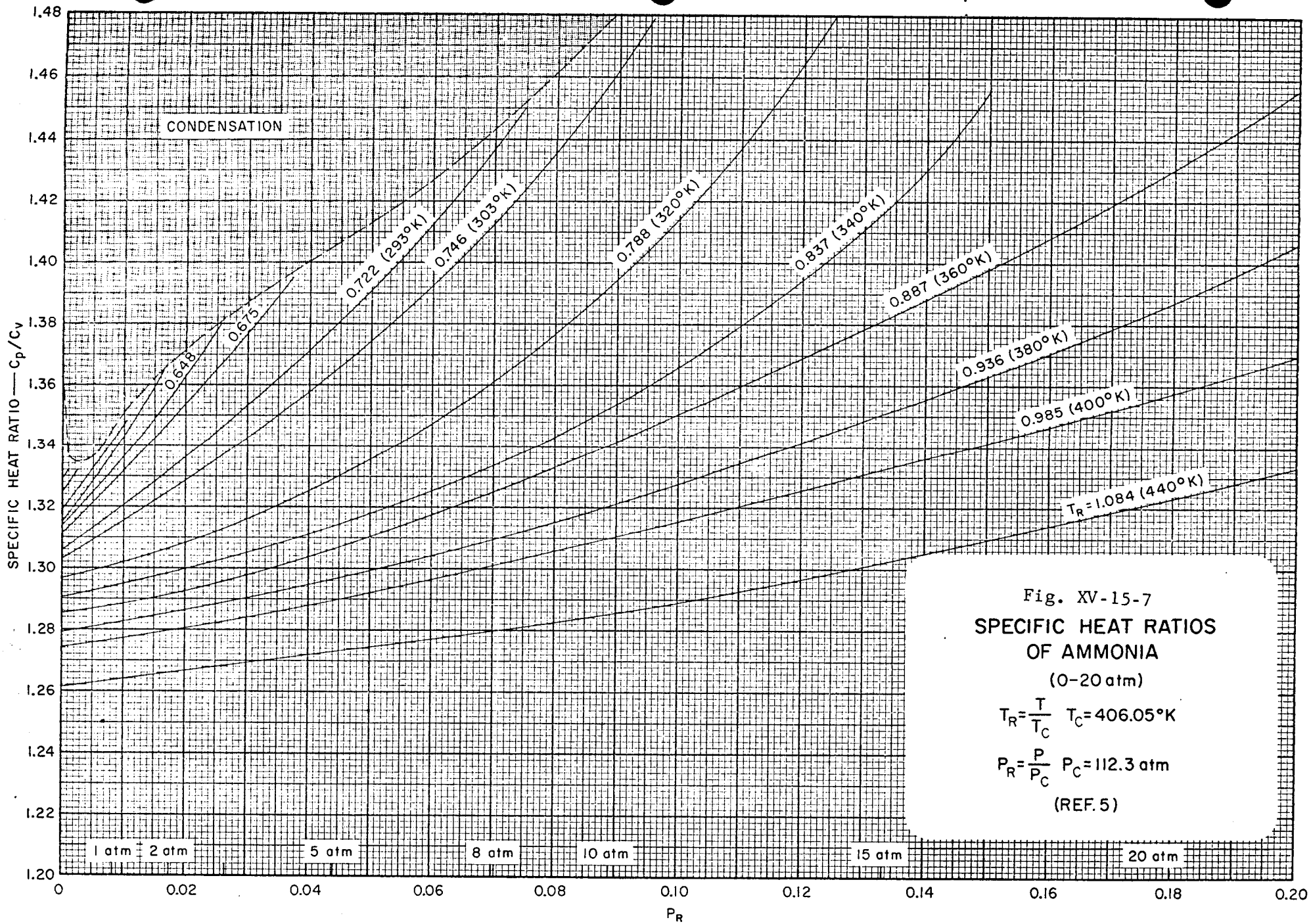

Fig. XV-15-7

SPECIFIC HEAT RATIOS OF AMMONIA

(0-20 atm)

$T_R = \frac{T}{T_C}$ $T_C = 406.05°K$

$P_R = \frac{P}{P_C}$ $P_C = 112.3$ atm

(REF. 5)

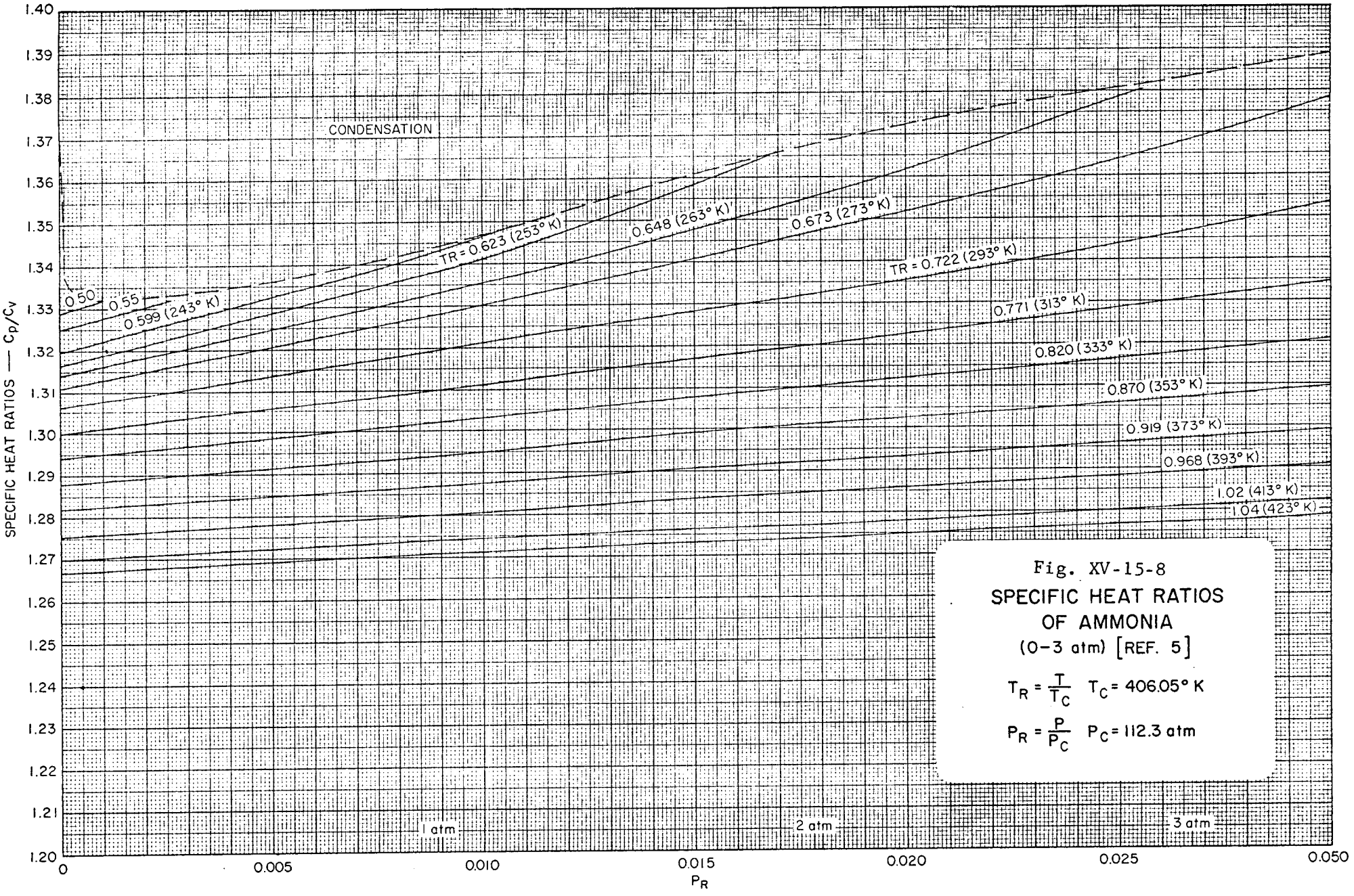

Fig. XV-15-8

SPECIFIC HEAT RATIOS OF AMMONIA (0–3 atm) [REF. 5]

$T_R = \frac{T}{T_C}$ $T_C = 406.05°$ K

$P_R = \frac{P}{P_C}$ $P_C = 112.3$ atm

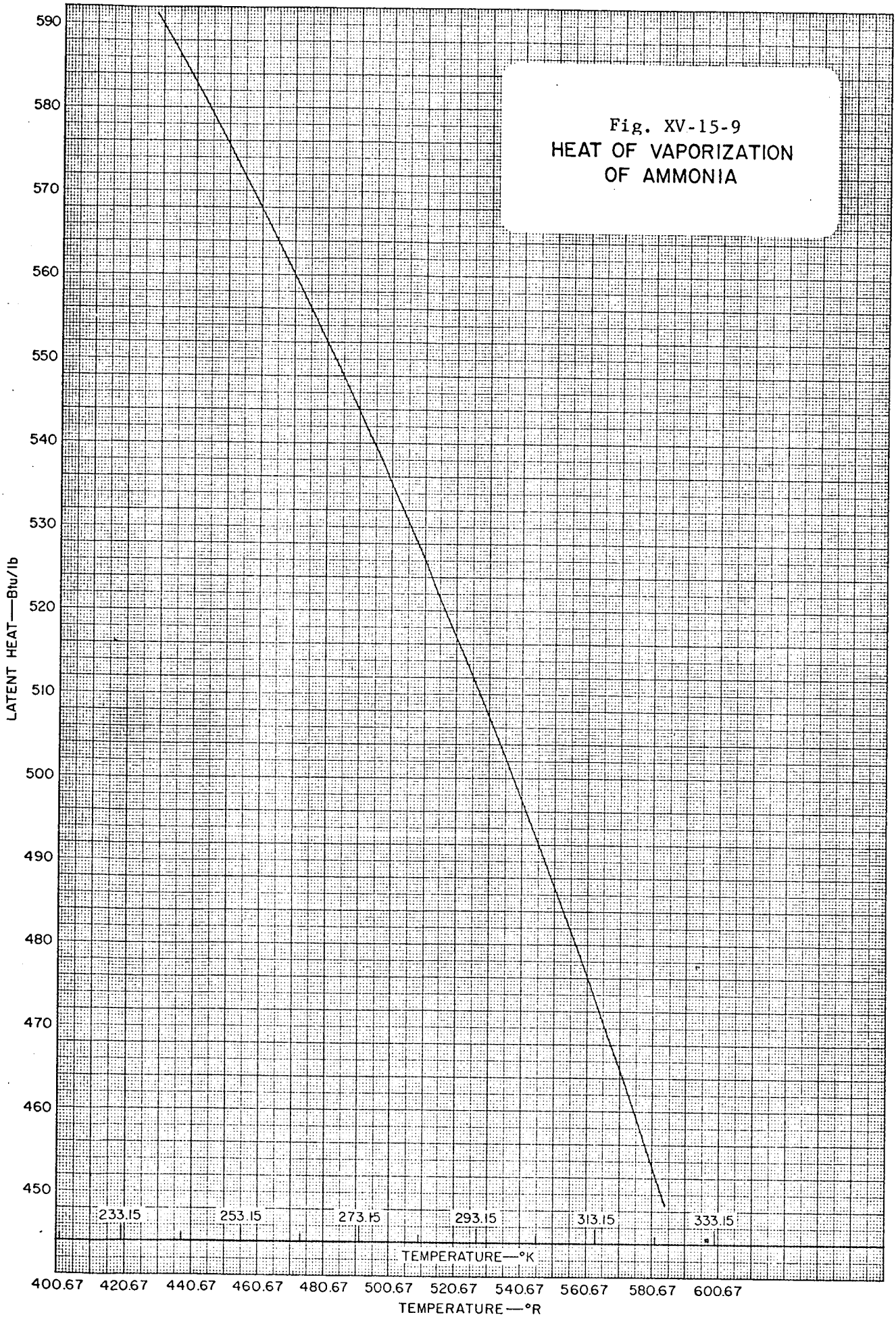

Fig. XV-15-9
HEAT OF VAPORIZATION
OF AMMONIA

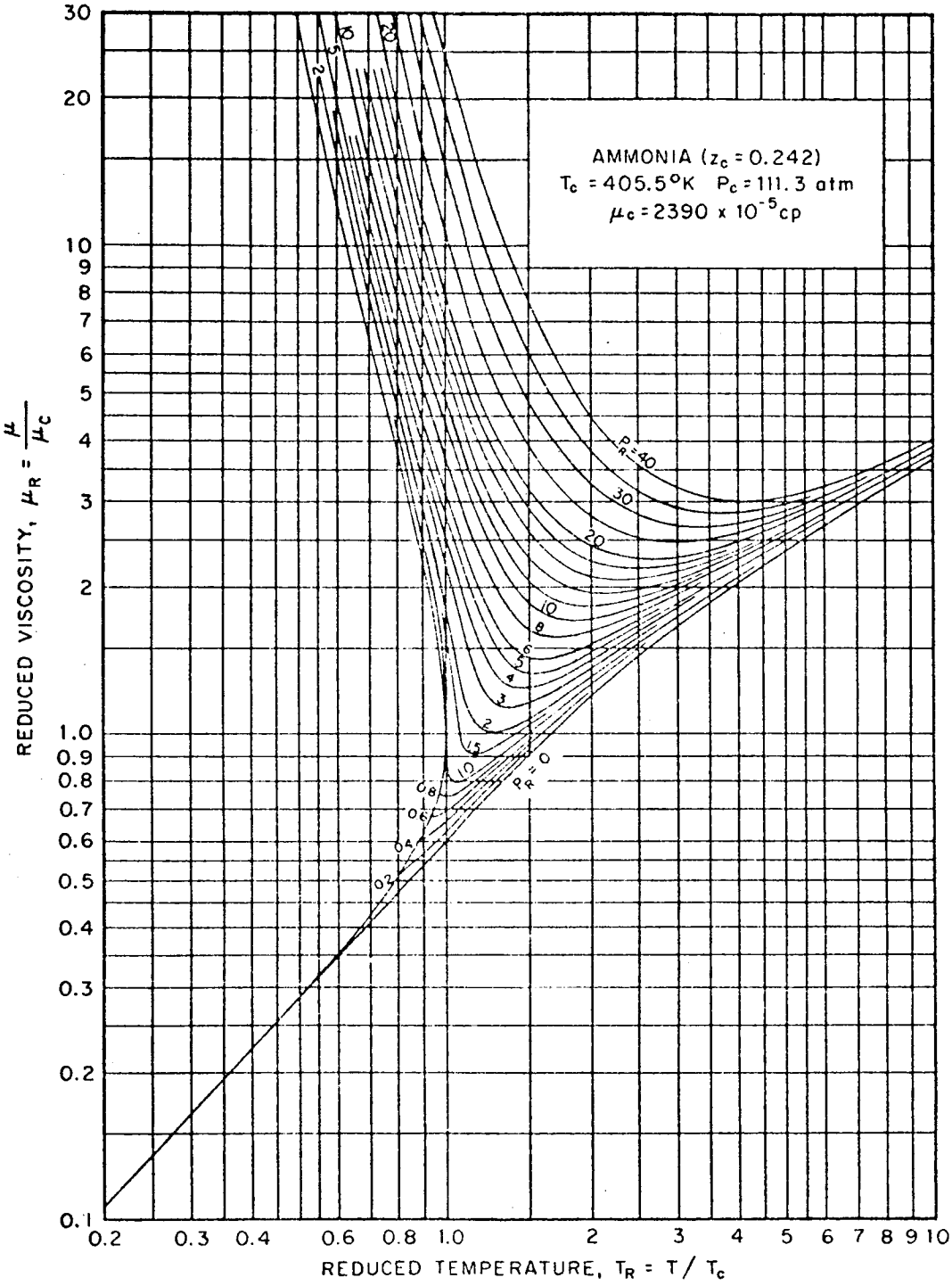

Fig. XV-15-10 VISCOSITY OF GASEOUS AND LIQUID AMMONIA*

*From: Groenier, W. S., and Thodos, G., *J. Chem. Eng. Data*, 6, No. 2, 243 (1961). (Ref. 3).

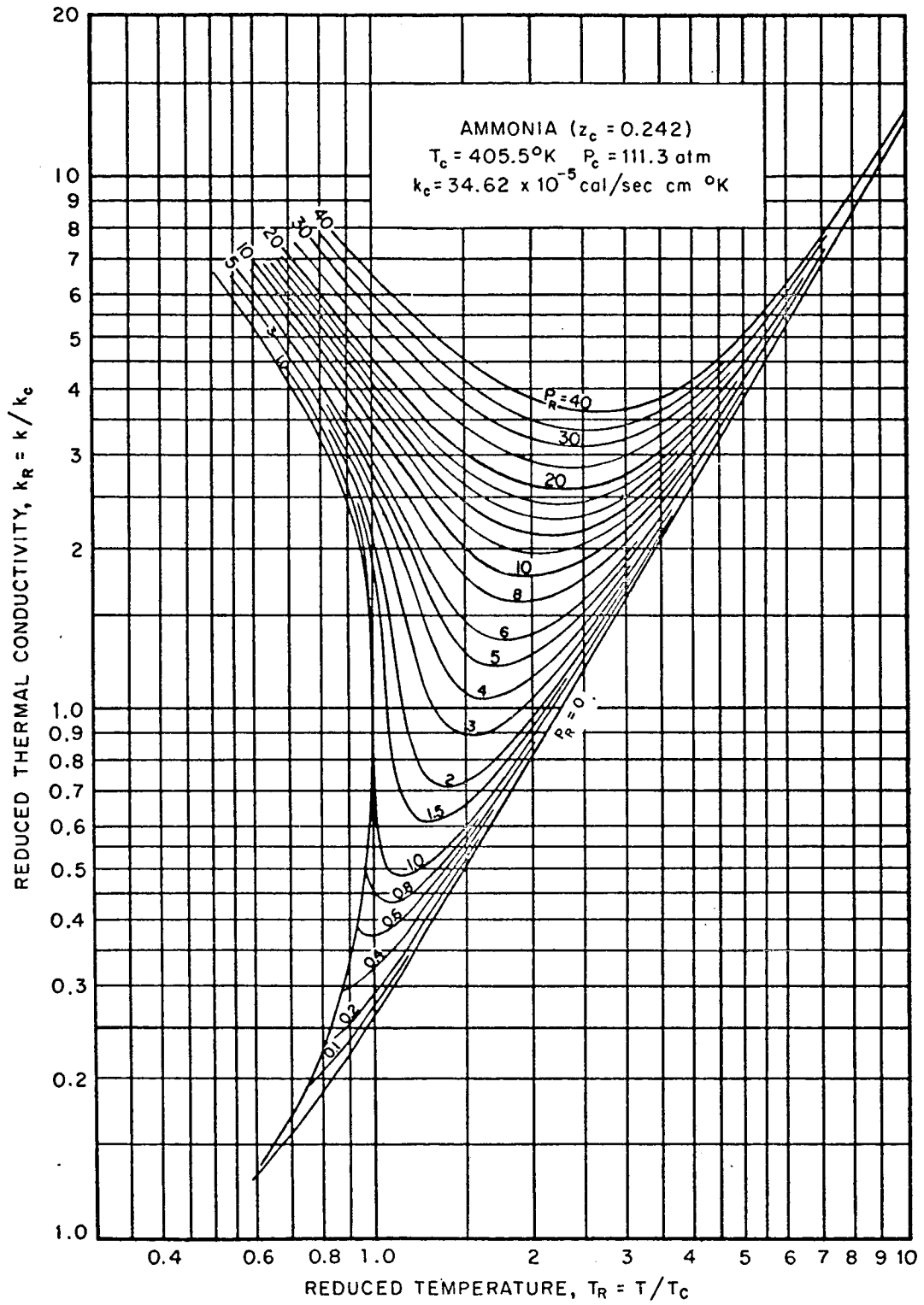

Fig. XV-15-11 THERMAL CONDUCTIVITY OF GASEOUS AND LIQUID AMMONIA*

*From: Groenier, W. S., and Thodos, G., *J. Chem. Eng. Data*, 6, No. 2, 244 (1961). (Ref. 3).

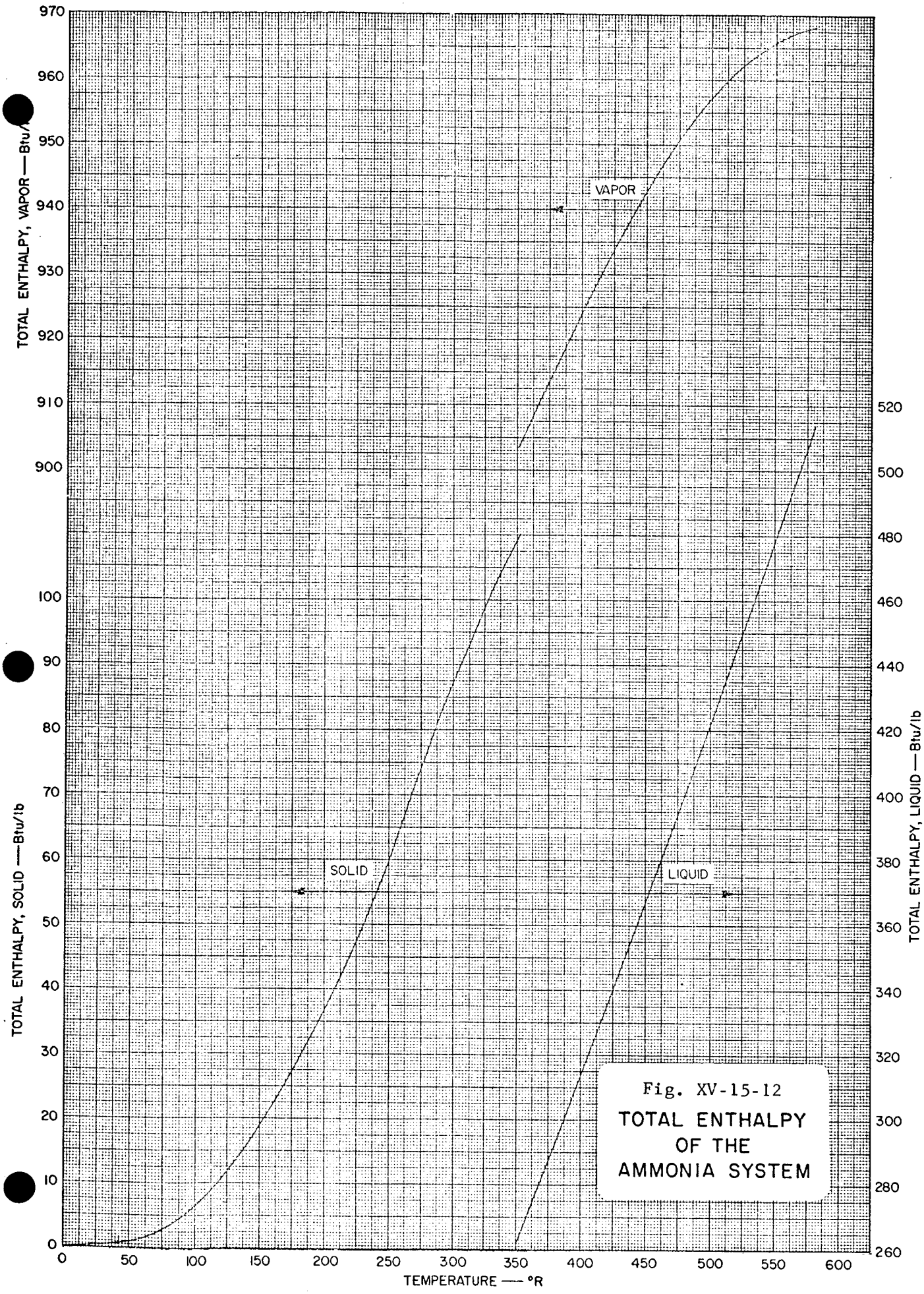

Fig. XV-15-12

TOTAL ENTHALPY OF THE AMMONIA SYSTEM

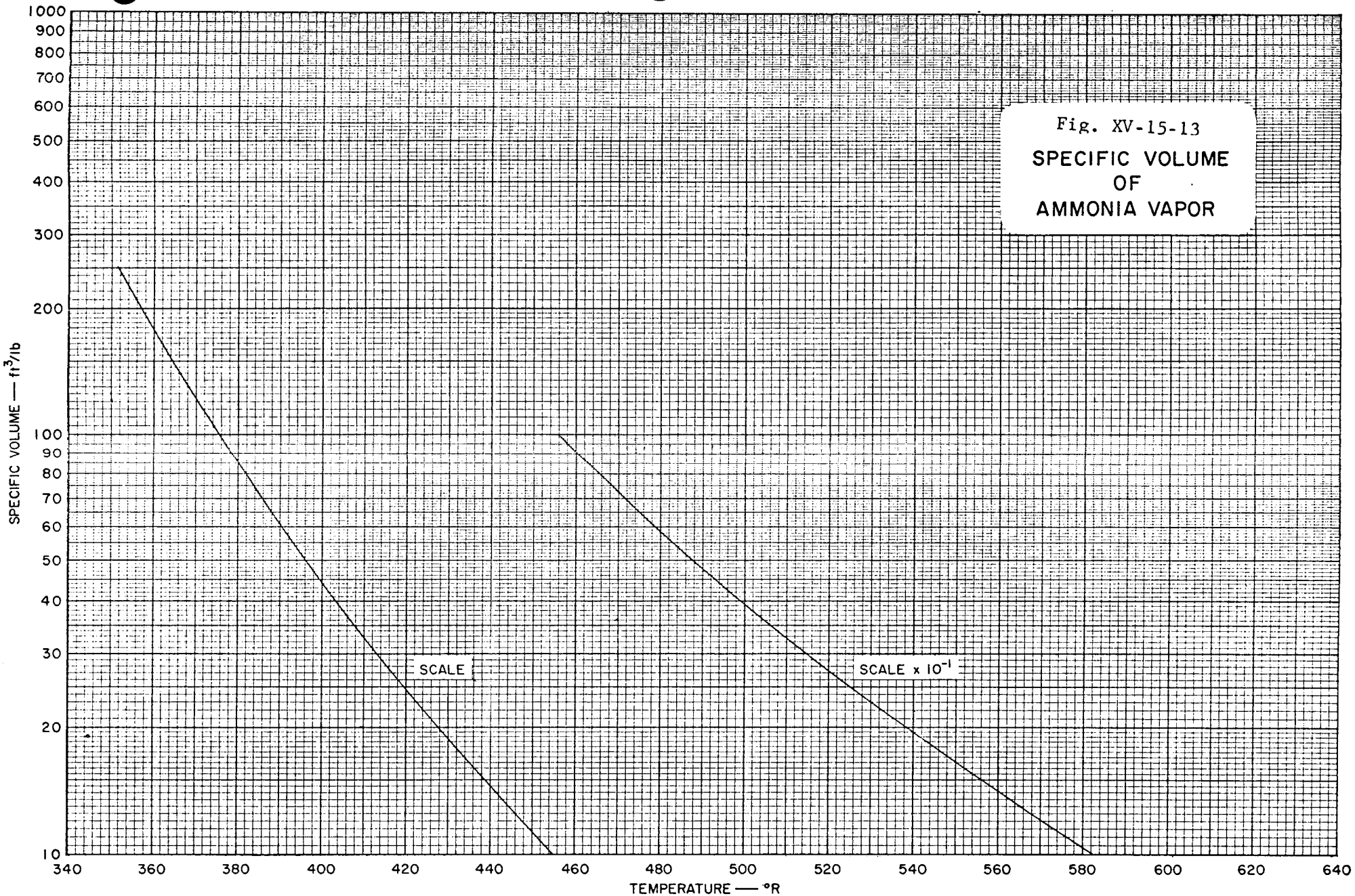

Fig. XV-15-13

SPECIFIC VOLUME OF AMMONIA VAPOR

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Table XV-16-1

GENERAL PROPERTIES OF HYDROGEN PEROXIDE

PROPERTY	TEMPERATURE				PRESSURE			REF
	°C	°K	°F	°R	psia	atm	mm of Hg	
Melting Point	0.41	272.74	31.26	490.93				4
Boiling Point	150.2	423.35	302.4	762.0				6
Triple Point	0.42	272.73	31.24	490.91				4
Critical Temp.	457	730	85.5	1315				6
Critical Press.					3145	214	--	6
Mol. Wt.	34.02							
Heat of Vaporization	362.6 cal/g or 652.7 Btu/lb at 25°C							5
Heat of Fusion	87.80 cal/g or 158.0 Btu/lb							4

Table XV-16-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR HYDROGEN PEROXIDE
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	2.41201	2.49216	1833.13	35.4471
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0386364	0.0399200	29.3637	0.567801
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	1.34001	1.38453	1018.41	19.6928
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.0214647	0.0221778	16.3131	0.315444
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-16-2

TOTAL VAPOR PRESSURE OF 98-100% HYDROGEN PEROXIDE SOLUTIONS (Ref. 6)

TEMPERATURE		PRESSURE	
°K	°R	psia	atm
263.2	473.8	0.002	0.00015
273.2	491.8	0.005	0.00036
283.2	509.8	0.012	0.00082
293.2	527.8	0.026	0.0018
303.2	545.8	0.054	0.0037
313.2	563.8	0.104	0.0071
323.2	581.8	0.192	0.0131
333.2	599.8	0.340	0.0231
343.2	617.8	0.578	0.0394
353.2	635.8	0.951	0.065
363.2	653.8	1.51	0.103
373.2	671.8	2.34	0.160
383.2	689.8	3.54	0.241

(See Figure XV-16-1)

Table XV-16-3

DENSITY OF HYDROGEN PEROXIDE
(Ref. 1)

TEMPERATURE		DENSITY	
°K	°R	g/cc	lb/ft^3
273.2	491.7	1.4710	91.83
298.2	536.7	1.4422	90.04
323.2	581.7	1.4134	88.24
369.2	664.5	1.358	84.78

(See Figure XV-16-2)

Table XV-16-4

SURFACE TENSION OF HYDROGEN PEROXIDE (Ref. 1)

TEMPERATURE		SURFACE TENSION-- dynes/cm	
°K	°R	100%	95.75%
273.15	491.67	83.3	82.93
293.15	527.67	80.4	79.87

Table XV-16-5

VISCOSITY OF HYDROGEN PEROXIDE
(Ref. 1)

TEMPERATURE		ABSOLUTE VISCOSITY— centipoises	
°K	°R	100%	98%
273.15	491.67	1.798	1.81
298.15	536.67	1.156	1.156
323.15	581.67	0.819	0.815

Table XV-16-6

HEAT CAPACITY OF SOLID HYDROGEN PEROXIDE (Ref. 4)

TEMPERATURE		HEAT CAPACITY	TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R	°K	°R	Btu/lb-°R
12	21.6	0.0018	70	126.0	0.1231
13	23.4	0.0023	75	135.0	0.1336
14	25.2	0.0029	80	144.0	0.1439
15	27.0	0.0036	85	153.0	0.1541
16	28.8	0.0044	90	162.0	0.1636
17	30.6	0.0053	95	171.0	0.1724
18	32.4	0.0063	100	180.0	0.1806
19	34.2	0.0074	110	198.0	0.1962
20	36.0	0.0087	120	216.0	0.2106
22	39.6	0.0114	130	234.0	0.2238
24	43.2	0.0145	140	252.0	0.2363
26	46.8	0.0180	150	270.0	0.2480
28	50.4	0.0216	160	288.0	0.2593
30	54.0	0.0256	170	306.0	0.2702
32	57.6	0.0298	180	324.0	0.2809
34	61.2	0.0342	190	342.0	0.2915
36	64.8	0.0389	200	360.0	0.3023
38	68.4	0.0436	210	378.0	0.3132
40	72.0	0.0484	220	396.0	0.3246
42	75.6	0.0533	230	414.0	0.3362
44	79.2	0.0583	240	432.0	0.3485
46	82.8	0.0634	250	450.0	0.361*
48	86.4	0.0684	255	459.0	0.369*
50	90.0	0.0736	260	468.0	0.381*
55	99.0	0.0864	265	477.0	0.406*
60	108.0	0.0991	268	482.4	0.461*
65	117.0	0.1115			

* Marked Premelting

Table XV-16-7

SPECIFIC HEAT OF 98% HYDROGEN PEROXIDE SOLUTION (Ref. 2)

TEMPERATURE		SPECIFIC HEAT
°K	°R	Btu/lb-°R
283.15	509.67	0.623
310.93	559.67	0.640
533.15	959.67	0.780

(See Figure XV-16-3)

Table XV-16-8

HEAT CAPACITY OF HYDROGEN PEROXIDE VAPOR (Ref. 4)

TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R
285	513.0	0.3202
290	522.0	0.3215
300	540.0	0.3240
310	558.0	0.3266
320	576.0	0.3292
330	594.0	0.3318
340	602.0	0.3344
350	620.0	0.3370

(See Figure XV-16-4)

Table XV-16-9

THERMAL CONDUCTIVITY OF 98% HYDROGEN PEROXIDE (Ref. 3)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft-°R
273.15	491.67	0.322
297.04	534.67	0.338
338.71	609.67	0.357
380.37	684.67	0.367
422.04	759.67	0.367
463.70	834.67	0.363

(See Figure XV-16-5)

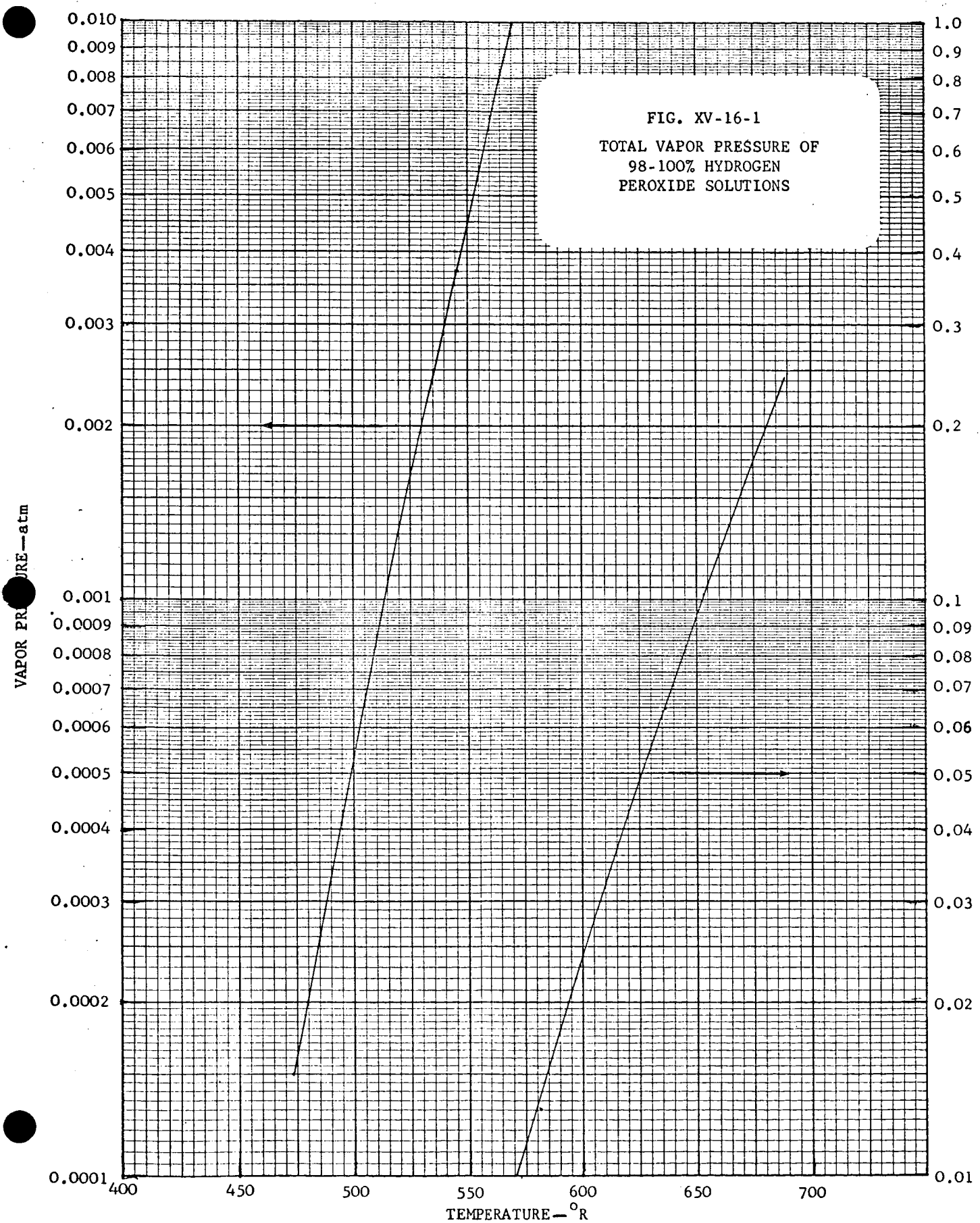
FIG. XV-16-1
TOTAL VAPOR PRESSURE OF
98-100% HYDROGEN
PEROXIDE SOLUTIONS
VAPOR PRESSURE—atm
TEMPERATURE—°R
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
400
450
500
550
600
650
700

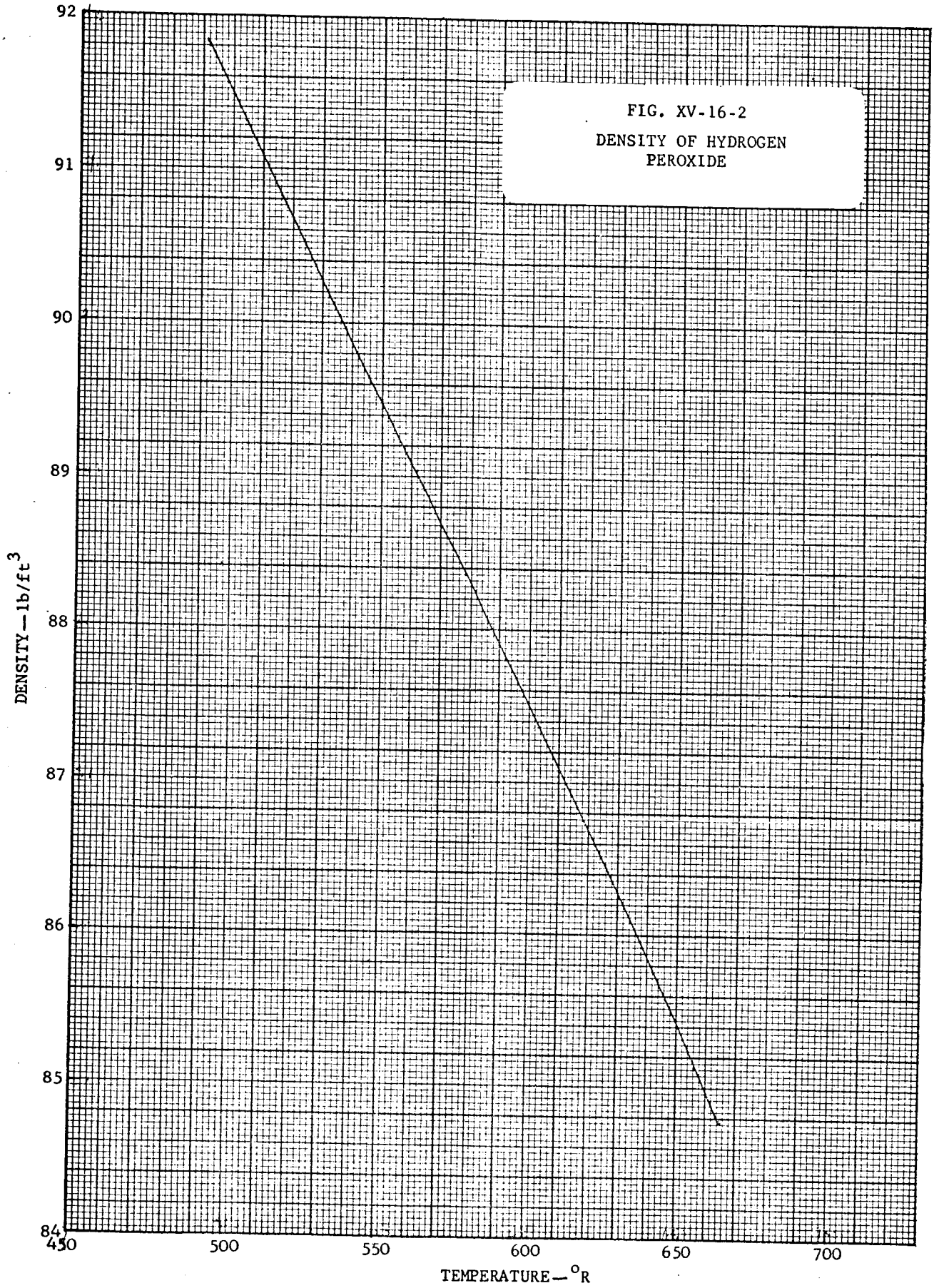

FIG. XV-16-2

DENSITY OF HYDROGEN PEROXIDE

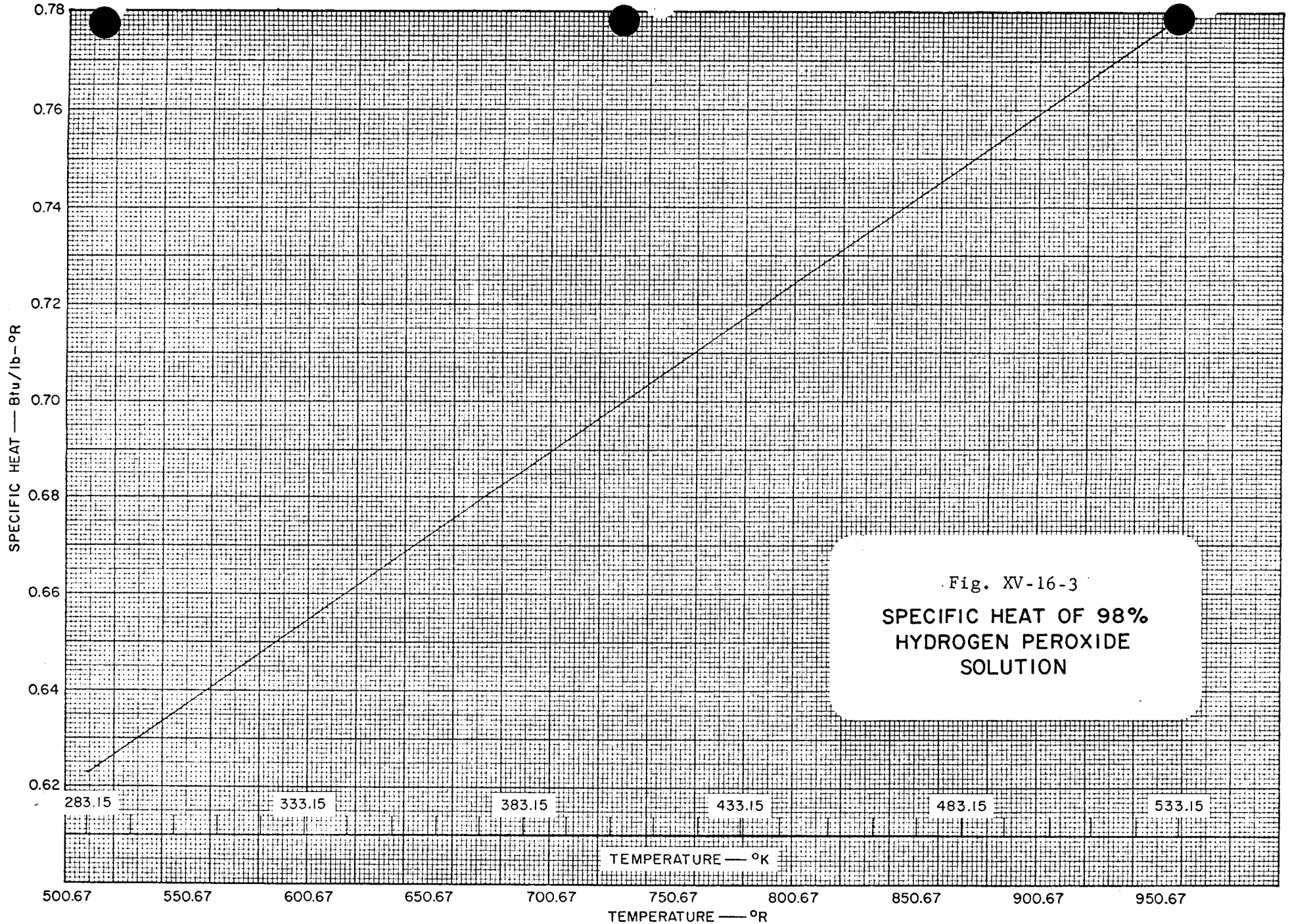

Fig. XV-16-3

SPECIFIC HEAT OF 98% HYDROGEN PEROXIDE SOLUTION

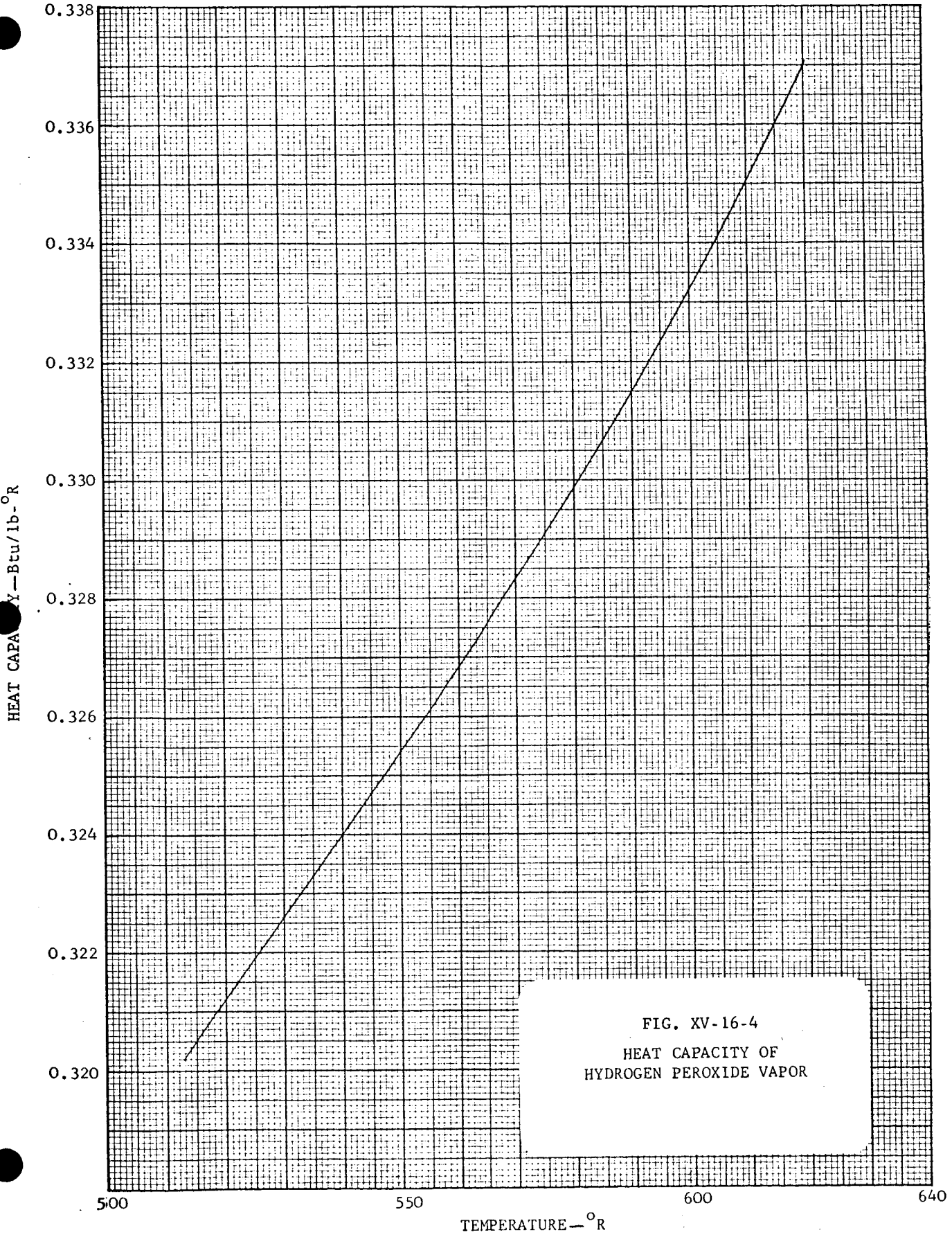

FIG. XV-16-4

HEAT CAPACITY OF
HYDROGEN PEROXIDE VAPOR

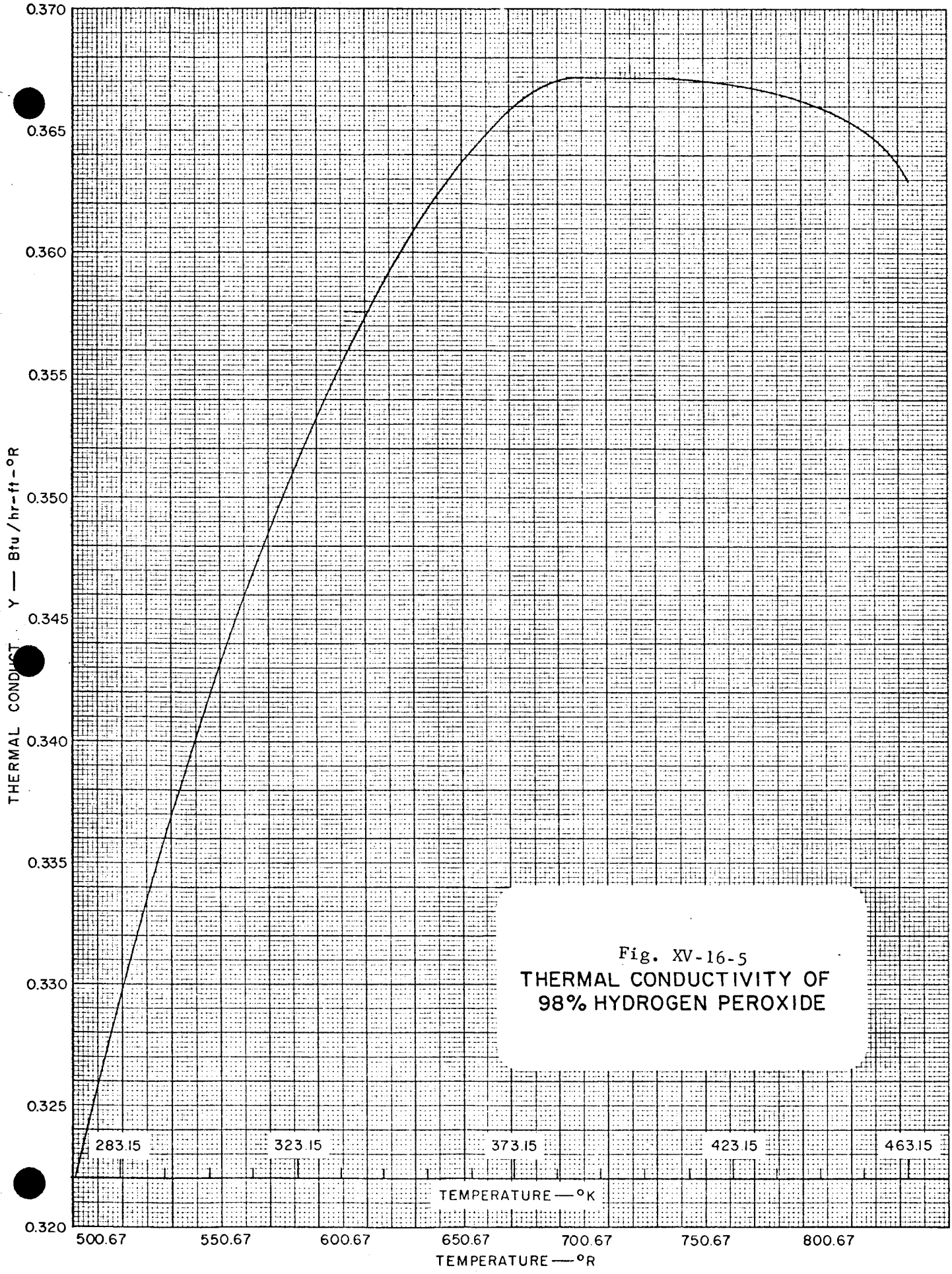

Fig. XV-16-5
THERMAL CONDUCTIVITY OF
98% HYDROGEN PEROXIDE

XV-16 HYDROGEN PEROXIDE REFERENCES

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Table XV-17-1

PHYSICAL CONSTANTS

OF

FREON-11

		REF.
Molecular Weight	137.38	5
Boiling Point @ 1 atm	74.79°F	5
Freezing Point @ 1 atm	-167.8°F	5
Specific Volume of Liquid @ 70°F	0.01079 cu-ft/lb	5
Vapor Pressure @ 70°F	13.4 psia	5
Specific Gravity, (Air = 1)	5.04	5
Density		
Liquid @ 86°F	91.398 lb/cu ft	5
Gas @ b.p.	0.3652 lb/cu ft	5
Critical Temperature	388.4°F	5
Critical Pressure	635 psia	5
Critical Density	34.586 lb/cu ft	5
Latent Heat of Vaporization @ b.p.	78.31 Btu/lb	5
Latent Heat of Fusion		
Specific Heat of Gas		
c_p @ 86°F	0.135 Btu/lb-°F	5
c_p @ 86°F	0.119 Btu/lb-°F	
Specific Heat Ratio, c_p/c_v	1.136	5
Thermal Conductivity @ 86°F, 1 atm	0.00484 Btu/hr-ft-°F	5
Viscosity		
Liquid @ 86°F	2.722×10^{-4} lb/ft-sec	5
Gas @ 86°F, 1 atm	7.459×10^{-6} lb/ft-sec	5
Solubility in Water @ 77°F, 1 atm	0.11% (by wt.)	5
Surface Tension @ 77°F	1.302×10^{-3} lb/ft	5

Table XV-17-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR FREON-11
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.597297	0.617144	453.946	8.77202
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.00956770	0.00988557	7.27145	0.140607
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.331832	0.342858	252.192	4.87662
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00531539	0.00549199	4.03969	0.0781147
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-17-2

VAPOR PRESSURE OF FREON-11 (Ref. 1)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
205.37	369.67	0.100	322.04	579.67	33.0
210.93	379.67	0.156	333.15	599.67	45.3
222.04	399.67	0.356	344.26	619.67	61.0
233.15	419.67	0.738	355.37	639.67	79.5
244.26	439.67	1.425	366.48	659.67	104.
255.37	459.67	2.55	377.59	679.67	130.
266.48	479.67	4.30	388.71	699.67	164.
277.59	499.67	7.00	399.82	719.67	204.
288.71	519.67	10.08	410.93	739.67	248.
299.82	539.67	16.25	422.04	759.67	300.
310.93	559.67	23.50			

(See Figure XV-17-1)

Table XV-17-3

DENSITY OF FREON-11 (Ref. 2)

PRESSURE psia / TEMP. °R	DENSITY-lb/ft^3								
	100	200	400	600	1000	1400	2000	4000	6000
600	86.6	86.8	87.1	87.4	87.9	88.4	89.1	-	-
650	2.0	81.8	82.4	82.8	83.5	84.3	85.3	87.7	89.5
700	2.0	76.3	76.9	77.5	78.6	79.6	81.0	84.3	86.6
750	1.9	4.0	70.7	71.6	73.4	74.6	76.4	80.7	83.6
800	1.6	3.8	10.0	63.4	66.7	68.9	71.3	76.9	80.6
850	1.5	3.3	8.2	18.4	56.8	61.7	65.7	72.9	77.3
900	1.4	3.2	7.3	13.6	40.0	52.5	59.6	68.9	74.0
950	1.4	2.9	6.4	11.4	27.0	41.5	52.4	65.0	70.5
1000	1.3	2.8	5.9	10.0	20.8	33.5	45.1	61.0	67.4
1050	1.3	2.6	5.4	9.0	17.7	25.5	39.6	57.0	64.5
1100	1.25	2.4	5.1	8.3	15.8	24.0	35.4	53.3	61.7
1150	1.15	2.3	4.8	7.6	14.3	21.3	31.3	50.1	58.8
1200	1.1	2.2	4.5	7.1	13.0	19.2	28.0	46.8	56.3

(See Figure XV-17-2)

NOTE: <u>All Data Extrapolated</u>

Table XV-17-4

VISCOSITY OF SATURATED LIQUID FREON-11 (Ref. 2)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises	°K	°R	centipoises
233.15	419.67	0.980	322.04	579.67	0.349
244.26	439.67	0.801	333.15	599.67	0.323
255.37	459.67	0.677	344.26	619.67	0.300
266.48	479.67	0.586	355.37	639.67	0.281
277.59	499.67	0.517	366.48	659.67	0.263
288.71	519.67	0.461	377.59	679.67	0.248
299.82	539.67	0.417	388.71	699.67	0.232
310.93	559.67	0.380			

(See Figure XV-17-3)

Table XV-17-5

VISCOSITY OF FREON-11 VAPOR AT ONE ATMOSPHERE (Ref. 2)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centipoises	°K	°R	centipoises
233.15	419.67	0.0088	322.04	579.67	0.0116
244.26	439.67	0.0092	333.15	599.67	0.0120
255.37	459.67	0.0096	344.26	619.67	0.0123
266.48	479.67	0.0099	355.37	639.67	0.0126
277.59	499.67	0.0103	366.48	659.67	0.0129
288.71	519.67	0.0106	377.59	679.67	0.0132
299.82	539.67	0.0110	388.71	699.67	0.0135
310.93	559.67	0.0113			

(See Figure XV-17-4)

Table XV-17-6

HEAT CAPACITY OF FREON-11
(Ref. 4)

TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R
100	180	0.07476
150	270	0.09485
200	360	0.1116
250	450	0.1251
298.16	536.70	0.1355
300	540	0.1359
400	720	0.1515
500	900	0.1616
600	1080	0.1682

(See Figure XV-16-5)

Table XV-17-7

THERMAL CONDUCTIVITY OF SATURATED FREON-11
(Ref. 2)

TEMPERATURE		THERMAL CONDUCTIVITY— Btu/hr-ft-°R	
°K	°R	Liquid	Vapor (at 1 atm)
253.15	455.67	0.060	
293.15	527.67	0.055	
303.15	545.67		0.00505
363.15	653.67		0.00621

(See Figure XV-16-6)

Table XV-17-8

SELECTED VALUES OF PROPERTIES OF SATURATED VAPOR OF FREON-11 (Ref. 7)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-$^\circ$R	
$^\circ$R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
359.69	0.0620	0.00948	453.1	105.5	0.002207	-11.86	92.36	80.50	-0.0304	0.2264
369.69	0.1000	0.00954	288.6	104.8	0.003467	- 9.87	91.51	81.64	-0.0250	0.2226
379.69	0.1570	0.00961	189.0	104.1	0.005292	- 7.89	90.68	82.79	-0.0197	0.2192
389.69	0.2392	0.00967	127.1	103.4	0.007868	- 5.91	89.86	83.95	-0.0146	0.2160
399.69	0.3562	0.00974	87.50	102.7	0.01143	- 3.94	89.06	85.12	-0.0096	0.2133
409.69	0.5184	0.00981	61.58	102.0	0.01624	- 1.97	88.27	86.30	-0.0047	0.2108
419.69	0.7391	0.00988	44.21	101.25	0.02262	0.00	87.48	87.48	0.0000	0.2085
429.69	1.034	0.00995	32.33	100.52	0.03093	1.97	86.70	88.67	0.0046	0.2064
439.69	1.420	0.01002	24.06	99.77	0.04157	3.94	95.93	89.87	0.0091	0.2046
449.69	1.920	0.01010	18.17	93.03	0.05503	5.91	85.16	91.07	0.0136	0.2030
459.69	2.555	0.01018	13.94	98.27	0.07176	7.89	84.38	92.27	0.0179	0.2015
469.69	3.352	0.01026	10.83	97.50	0.09233	9.88	83.60	93.48	0.0222	0.2003
479.69	4.342	0.01034	8.519	96.72	0.1174	11.87	82.82	94.69	0.0264	0.1991
489.69	5.557	0.01042	6.776	95.94	0.1476	13.88	82.03	95.91	0.0306	0.1981
499.69	7.032	0.01051	5.447	95.14	0.1836	15.89	81.22	97.11	0.0346	0.1972
509.69	8.804	0.01060	4.421	94.34	0.2262	17.92	80.40	98.32	0.0386	0.1964
519.69	10.90	0.01069	3.626	93.53	0.2758	19.96	79.57	99.53	0.0426	0.1958
529.69	13.40	0.01079	2.993	92.71	0.3342	22.02	78.71	100.73	0.0465	0.1951
539.69	16.31	0.01088	2.492	91.88	0.4012	24.09	77.84	101.93	0.0504	0.1947
549.69	19.69	0.01098	2.091	91.04	0.4783	26.18	76.95	103.12	0.0542	0.1942
559.69	23.60	0.01109	1.765	90.19	0.5666	28.27	76.03	104.30	0.0580	0.1938
569.69	28.09	0.01119	1.499	89.34	0.6671	30.40	75.08	105.47	0.0617	0.1935
579.69	33.20	0.01130	1.281	88.47	0.7808	32.53	74.10	106.63	0.0654	0.1933
589.69	38.96	0.01142	1.101	87.60	0.9080	34.67	73.11	107.78	0.0691	0.1931
599.69	45.50	0.01154	0.951	86.69	1.052	36.84	72.07	108.91	0.0727	0.1929

Table XV-17-8 (contd)

SELECTED VALUES OF PROPERTIES OF SATURATED VAPOR OF FREON-11 (Ref. 7)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-^{o}R	
^{o}R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
609.69	52.85	0.01166	0.824	85.78	1.214	39.02	71.00	110.02	0.0763	0.1927
619.69	61.04	0.01179	0.718	84.85	1.394	41.23	69.89	111.12	0.0798	0.1926
629.69	70.00	0.01198	0.617	83.5	1.620	43.8	68.7	112.5	0.0833	0.1924
639.69	80.00	0.01214	0.534	82.4	1.870	46.4	67.6	114.0	0.0865	0.1922
649.69	91.00	0.01226	0.472	81.6	2.120	48.6	66.5	115.1	0.0899	0.1923
659.69	102.00	0.01239	0.422	80.7	2.370	50.8	65.4	116.2	0.0932	0.1924
669.69	117.00	0.01262	0.380	79.2	2.630	53.1	63.9	117.0	0.0972	0.1926
679.69	131.00	0.01275	0.334	78.5	2.990	55.5	62.7	118.2	0.1004	0.1927
689.69	147.00	0.01293	0.292	77.3	3.425	58.0	61.1	119.1	0.1043	0.1929
699.69	164.00	0.01312	0.263	76.2	3.800	60.5	59.5	120.0	0.1080	0.1930
709.69	182.00	0.01331	0.240	75.1	4.170	62.7	58.1	120.8	0.1112	0.1931
719.69	202.00	0.01349	0.213	74.1	4.690	65.0	56.7	121.7	0.1143	0.1931
729.69	226.00	0.01373	0.189	72.8	5.290	67.5	55.1	122.6	0.1177	0.1932
739.69	250.00	0.01396	0.169	71.6	5.920	70.0	53.5	123.5	0.1209	0.1932
749.69	276.00	0.0142	0.153	70.4	6.540	72.5	51.7	124.2	0.1241	0.1931
759.69	302.00	0.0145	0.140	68.9	7.160	75.0	50.0	125.0	0.1271	0.1929
769.69	332.00	0.01485	0.123	67.3	8.100	77.5	48.0	125.5	0.1303	0.1927
779.69	362.00	0.1525	0.110	65.5	9.060	80.0	45.7	125.7	0.1338	0.1924
789.69	395.00	0.0157	0.098	63.7	10.22	83.5	42.4	125.9	0.1381	0.1918
799.69	430.00	0.01622	0.087	61.6	11.52	87.0	38.7	125.7	0.1429	0.1913
809.69	468.00	0.01683	0.078	59.4	12.77	90.5	34.9	125.4	0.1474	0.1905
819.69	507.00	0.0177	0.067	56.5	15.00	94.0	30.8	124.8	0.1517	0.1893
829.69	545.00	0.01875	0.058	53.3	17.13	98.0	25.6	123.6		
839.69	590.00	0.02083	0.046	48.0	21.80	103.0	19.3	122.3		
848.09 (Critical)	635.00	0.0290	0.029	34.5	34.50	113.4	0	113.4		

V = volume in cu-ft/lb
H = enthalpy in btu/lb
S = entropy in btu/lb-°R
(saturated properties in parentheses)

Table XV-17-9.1

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 At 1, 2, 3, 5 psia (Ref. 6)

TEMPERATURE	1 psia (sat'n temp. 428.69°R)			2 psia (sat'n temp. 451.09°R)			3 psia (sat'n temp. 465.59°R)			5 psia (sat'n temp. 485.29°R)		
°R	V	H	S	V	H	S	V	H	S	V	H	S
(at sat'n)	(33.37)	(88.55)	(0.2066)									
429.69	33.43	88.67	0.2069									
439.69	34.22	89.90	.2097	(17.50)	(91.24)	(0.2028)						
449.69	35.00	91.13	.2125	...	...	...	(12.01)	(92.98)	(0.2008)			
459.69	35.79	92.36	.2153	17.83	92.31	0.2052	...	...	...			
469.69	36.57	93.61	.2180	18.23	93.56	.2079	12.11	93.50	0.2019	(7.475)	(95.38)	(0.1985)
479.69	37.36	94.87	.2206	18.62	94.82	.2105	12.38	94.76	.2046	...	...	...
489.69	38.14	96.14	.2232	19.02	96.09	.2131	12.64	96.04	.2072	7.543	95.94	0.1997
499.69	38.93	97.42	.2258	19.41	97.37	.2157	12.91	97.32	.2098	7.703	97.22	.2023
509.69	39.71	98.71	.2284	19.81	98.66	.2183	13.17	98.61	.2123	7.863	98.51	.2048
519.69	40.50	100.02	.2209	20.20	99.97	.2208	13.43	99.92	.2149	8.023	99.82	.2074
529.69	41.28	101.33	.2334	20.59	101.28	.2233	13.70	101.23	.2174	8.182	101.14	.2099
539.69	42.07	102.66	.2359	20.99	102.61	.2258	13.96	102.56	.2199	8.341	102.47	.2124
549.69	42.85	103.99	.2383	21.38	103.94	.2282	14.22	103.90	.2223	8.500	103.80	.2148
559.69	43.63	105.33	.2407	21.77	105.28	.2307	14.49	105.24	.2247	8.659	105.16	.2173
569.69	44.42	106.68	.2431	22.17	106.64	.2331	14.75	106.60	.2271	8.818	106.51	.2197
579.69	45.20	108.05	.2455	22.56	108.01	.2354	15.01	107.97	.2295	8.977	107.88	.2220
589.69	45.98	109.42	.2478	22.95	109.38	.2378	15.28	109.34	.2319	9.135	109.26	.2244
599.69	46.55	110.80	.2502	23.35	110.76	.2401	15.54	110.72	.2342	9.294	110.65	.2267
609.69	47.55	112.20	.2525	23.74	112.17	.2424	15.80	112.12	.2365	9.452	112.05	.2290

Table XV-17-9.1 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 At 1, 2, 3, 5 psia

TEMPERATURE	1 psia (sat'n temp. 428.69°R)			2 psia (sat'n temp. 451.09°R)			3 psia (sat'n temp. 465.59°R)			5 psia (sat'n temp. 485.29°R)		
°R	V	H	S	V	H	S	V	H	S	V	H	S
619.69	48.33	113.60	.2548	24.13	113.57	.2447	16.06	113.53	.2388	9.610	113.45	.2313
629.69	49.12	115.02	.2571	24.52	114.98	.2470	16.33	114.95	.2411	9.769	114.87	.2336
639.69	49.90	116.45	.2593	24.92	116.41	.2492	16.59	116.38	.2433	9.927	116.30	.2359
649.69	50.68	117.89	.2615	25.31	117.85	.2515	16.85	117.81	.2456	10.09	117.74	.2381
659.69	51.47	119.34	.2637	25.70	119.30	.2537	17.11	119.26	.2478	10.25	119.19	.2403
669.69	52.25	120.80	.2659	26.10	120.76	.2559	17.38	120.72	.2500	10.40	120.65	.2425
679.69	53.03	122.26	.2681	26.49	122.22	.2581	17.64	122.19	.2522	10.56	122.12	.2447
689.69	53.82	123.74	.2703	26.88	123.70	.2602	17.90	123.67	.2543	10.72	123.60	.2469
699.69	54.60	125.23	.2724	27.27	125.19	.2624	18.16	125.16	.2565	10.88	125.09	.2490
709.69	55.38	126.73	.2745	27.66	126.69	.2645	18.43	126.66	.2586	11.04	126.59	.2511
719.69	56.16	128.24	.2766	28.06	128.21	.2666	18.69	128.17	.2607	11.19	128.11	.2533
729.69	56.95	128.76	.2787	28.45	129.73	.2687	18.95	129.70	.2628	11.35	129.63	.2554
739.69				28.84	131.26	.2708	19.21	131.23	.2649	11.51	131.16	.2574
749.69				29.23	132.80	.2728	19.47	132.77	.2670	11.67	132.71	.2595
759.69				29.62	134.35	.2749	19.74	134.32	.2690	11.82	134.27	.2616
769.69							20.00	135.88	.2711	11.98	135.83	.2636
779.69										12.14	137.40	.2656
789.69										12.30	138.98	.2677

Table XV-17-9.2

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 AT 10, 20, 30, 40 psia (Ref. 6)

TEMPERATURE	10 psia (sat'n temp. 515.59°R)			20 psia (sat'n temp. 550.49°R)			30 psia (sat'n temp. 573.59°R)			40 psia (sat'n temp. 591.29°R		
°R	V	H	S	V	H	S	V	H	S	V	H	S
(at sat'n)	(3.928)	(99.04)	(0.1960)									
509.69	...	...	...									
519.69	3.961	99.57	0.1970									
529.69	4.042	100.89	.1996	(2.061)	(103.22)	(0.1942)						
539.69	4.123	102.23	.2021	...	...	...						
549.69	4.204	103.57	.2045	...	...	...						
559.69	4.285	104.93	.2070	2.099	104.47	0.1964	(1.409)	(105.93)	(0.1935)			
569.69	4.366	106.29	.2094	2.140	105.84	.1989	...	...	...			
579.69	4.447	107.67	.2118	2.182	107.23	.2013	1.426	106.79	0.1949	(1.074)	(107.96)	(0.1930)
589.69	4.528	109.05	.2141	2.224	108.63	.2036	1.455	108.19	.1973	...	...	...
599.69	4.609	110.44	.2165	2.266	110.03	.2060	1.484	109.60	.1997	1.091	109.17	0.1950
609.69	4.690	111.85	.2188	2.307	111.44	.2083	1.513	111.02	.2020	1.115	110.60	0.1974
619.69	4.771	113.26	.2211	2.349	112.87	.2107	1.541	112.45	.2044	1.137	112.04	.1997
629.69	4.851	114.69	.2234	2.390	114.31	.2130	1.569	113.90	.2067	1.159	113.49	.2021
639.69	4.932	116.12	.2257	2.431	115.75	.2152	1.598	115.35	.2090	1.181	114.95	.2044
649.69	5.012	117.56	.2279	2.473	117.19	.2175	1.626	116.81	.2112	1.202	116.42	.2067
659.69	5.092	119.01	.2301	2.514	118.65	.2197	1.654	118.27	.2135	1.224	117.89	.2089
669.69	5.171	120.48	.2323	2.555	120.12	.2219	1.682	119.75	.2157	1.246	119.38	.2112
679.69	5.251	121.95	.2345	2.596	121.60	.2241	1.711	121.24	.2179	1.268	120.88	.2134
689.69	5.331	123.43	.2367	2.637	123.09	.2263	1.739	122.74	.2201	1.289	122.39	.2156
699.69	5.411	124.92	.2388	2.678	124.59	.2285	1.767	124.25	.2223	1.311	124.91	.2178
709.69	5.491	126.43	.2409	2.719	126.11	.2306	1.794	125.77	.2244	1.332	125.44	.2199

Table XV-17-9.2 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 AT 10, 20, 30, 40 psia

TEMPERATURE	10 psia (sat'n temp. 515.59°R)			20 psia (sat'n temp. 550.49°R)			30 psia (sat'n temp. 573.59°R)			40 psia (sat'n temp. 591.29°R		
°R	V	H	S	V	H	S	V	H	S	V	H	S
719.69	5.571	127.95	.2431	2.760	127.63	.2328	1.822	127.30	.2266	1.353	126.97	.2221
729.69	5.650	129.48	.2452	2.800	129.16	.2349	1.850	128.84	.2287	1.374	128.52	.2242
739.69	5.730	131.01	.2473	2.841	130.70	.2370	1.878	130.39	.2308	1.396	130.08	.2263
749.69	5.809	132.56	.2494	2.881	132.25	.2391	1.905	131.95	.2329	1.417	131.64	.2284
759.69	5.889	134.12	.2514	2.922	133.82	.2411	1.933	133.52	.2350	1.438	133.22	.2305
769.69	5.969	135.68	.2535	2.962	135.39	.2432	1.960	135.10	.2370	1.459	134.80	.2326
779.69	6.048	137.26	.2555	3.003	136.97	.2452	1.988	136.68	.2391	1.480	136.40	.2347
789.69	6.127	138.84	.2575	3.043	138.56	.2472	2.015	138.28	.2411	1.501	138.00	.2367
799.69	6.206	140.43	.2595	3.084	140.16	.2493	2.043	139.89	.2431	1.522	139.61	.2387
809.69	6.285	142.04	.2615	3.124	141.77	.2513	2.070	141.51	.2452	1.543	141.24	.2407
819.69	6.365	143.66	.2635	3.164	143.40	.2532	2.097	143.14	.2472	1.564	142.88	.2427
829.69				3.205	145.03	.2552	2.125	144.78	.2491	1.584	144.52	.2447
839.69				3.245	146.68	.2572	2.152	146.43	.2511	1.605	146.18	.2467
849.69				3.286	148.33	.2592	2.179	148.09	.2531	1.626	147.83	.2487
859.69				3.326	149.99	.2611	2.207	149.75	.2550	1.647	149.51	.2506
869.69							2.234	151.43	.2570	1.668	151.19	.2526
879.69							2.261	153.12	.2589	1.688	152.89	.2545
889.69										1.709	154.59	.2564
899.69										1.729	156.30	.2583
909.69										...	...	...

Table XV-17-9.3

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 at 50, 60 psia (Ref. 6)

TEMPERATURE	50 psia (sat'n temp. 605.99°R)			60 psia (sat'n temp. 618.49°R)		
°R	V	H	S	V	H	S
579.69	(0.8689)	(109.62)	(0.1928)			
589.69	...	...	...			
599.69	...	...	...			
609.69	0.8756	110.16	0.1937	(0.7297)	(110.99)	(0.1926)
619.69	.8937	111.61	.1960	0.7314	111.17	0.1929
629.69	.9118	113.08	.1984	.7471	112.65	.1953
639.69	.9299	114.55	.2007	.7627	114.14	.1976
649.69	.9477	116.03	.2030	.7782	115.63	.1999
659.69	.9656	117.52	.2053	.7937	117.13	.2022
669.69	.9835	119.02	.2075	.8090	118.64	.2045
679.69	1.002	120.52	.2098	.8241	120.16	.2068
689.69	1.019	122.04	.2120	.8391	121.68	.2090
699.69	1.037	123.56	.2142	.8541	123.21	.2112
709.69	1.054	125.10	.2164	.8691	124.76	.2134
719.69	1.072	126.64	.2185	.8839	126.31	.2156
729.69	1.089	128.20	.2207	.8987	127.87	.2177
739.69	1.106	129.76	.2228	.9134	129.44	.2198
749.69	1.124	131.33	.2249	.9281	131.01	.2220
759.69	1.141	132.91	.2270	.9427	132.60	.2241

Table XV-17-9.3 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-11 at 50, 60 psia

TEMPERATURE	50 psia (sat'n temp. 605.99°R)			60 psia (sat'n temp. 618.49°R)		
°R	V	H	S	V	H	S
769.59	1.158	134.50	.2291	.9574	134.20	.2262
779.69	1.175	136.10	.2311	.9719	135.81	.2282
789.69	1.192	137.71	.2332	.9863	137.42	.2303
799.69	1.209	139.33	.2352	1.001	139.05	.2323
809.69	1.226	140.96	.2373	1.015	140.69	.2344
819.69	1.243	142.61	.2393	1.030	142.33	.2364
829.69	1.260	144.26	.2413	1.044	143.98	.2384
839.69	1.277	145.92	.2433	1.059	145.65	.2404
849.69	1.294	147.58	.2452	1.073	147.32	.2424
859.69	1.311	149.26	.2472	1.087	149.01	.2443
869.69	1.328	150.95	.2492	1.101	150.70	.2463
879.69	1.345	152.65	.2511	1.115	152.41	.2483
889.69	1.361	154.36	.2530	1.130	154.12	.2502
899.69	1.378	156.07	.2549	1.144	155.84	.2521
909.69	1.395	157.80	.2569	1.158	157.57	.2540
919.69				1.172	159.31	.2559
929.69				...	...	...

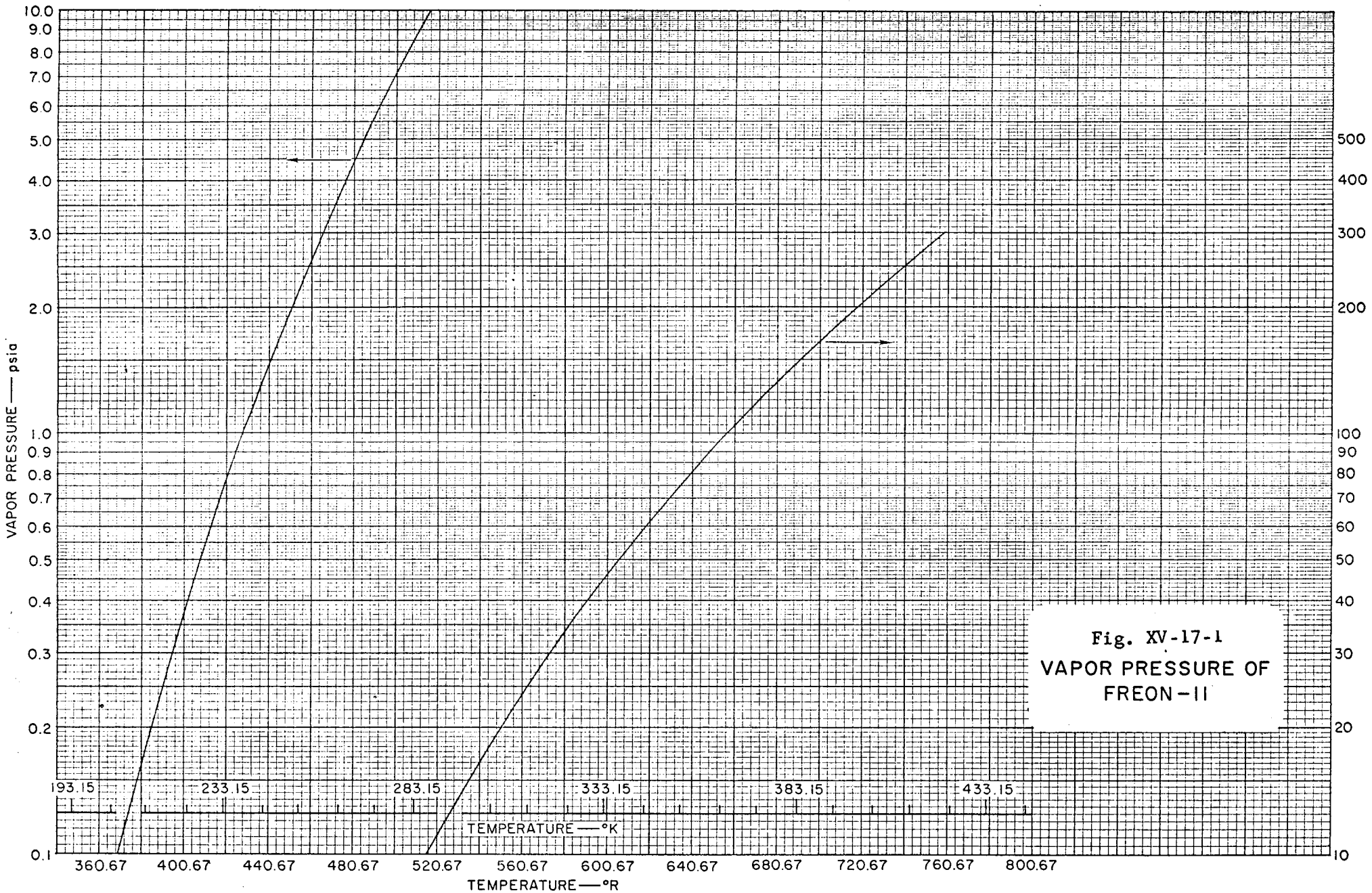


Fig. XV-17-1
VAPOR PRESSURE OF FREON-11

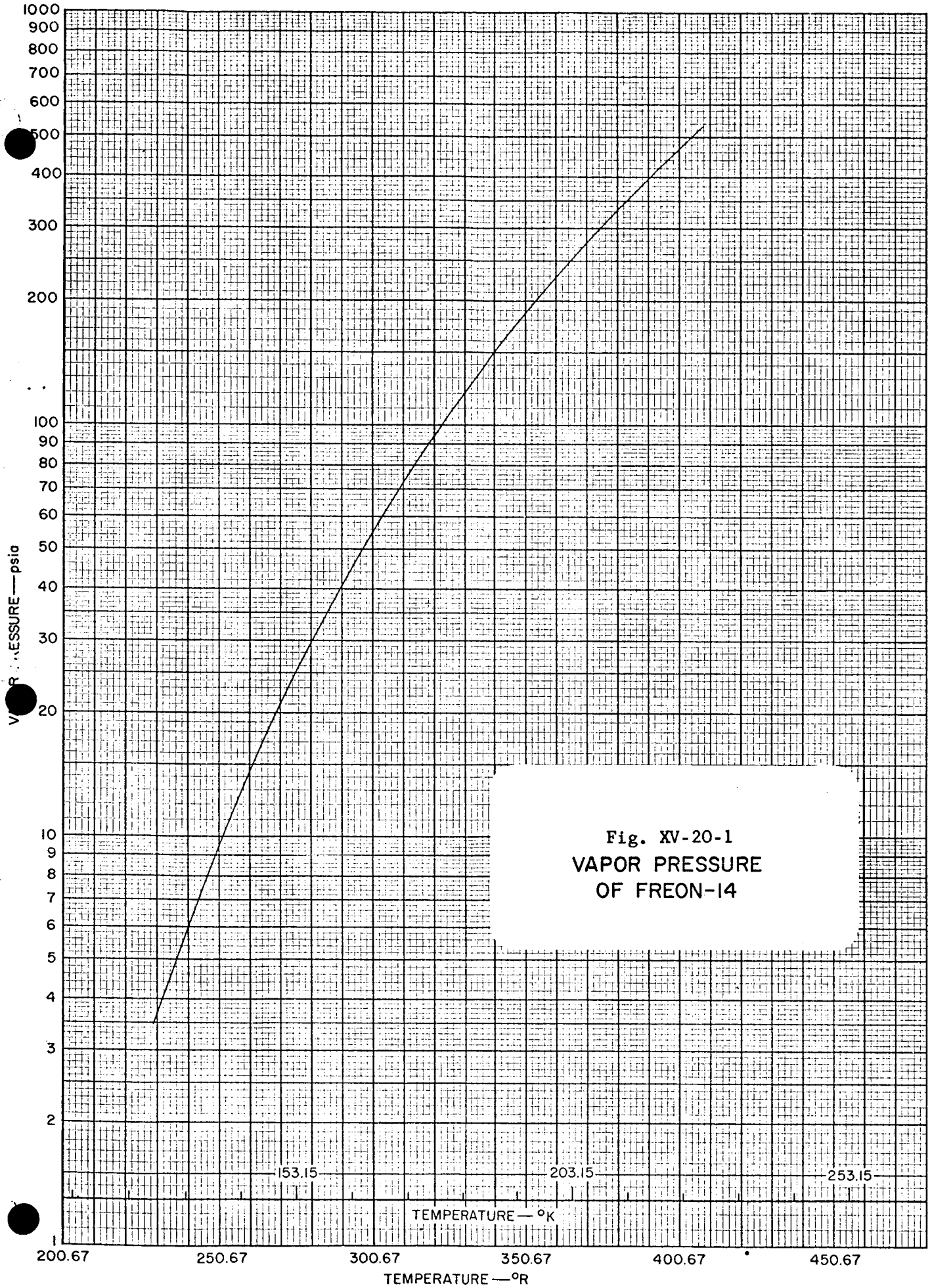
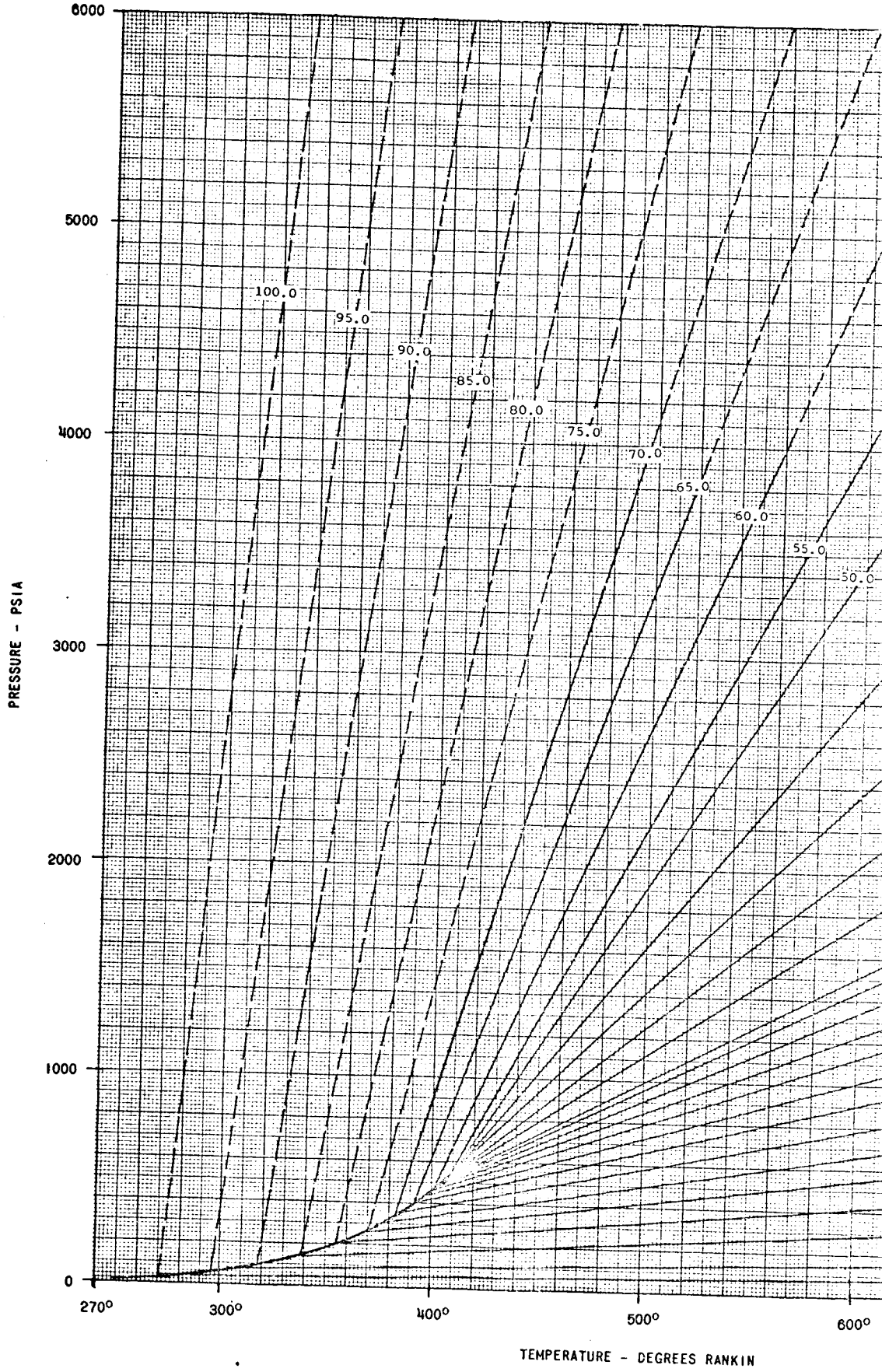


Fig. XV-20-1
VAPOR PRESSURE
OF FREON-14


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
270°
300°
400°
500°
600°
TEMPERATURE - DEGREES RANKIN

XV-20-2-1

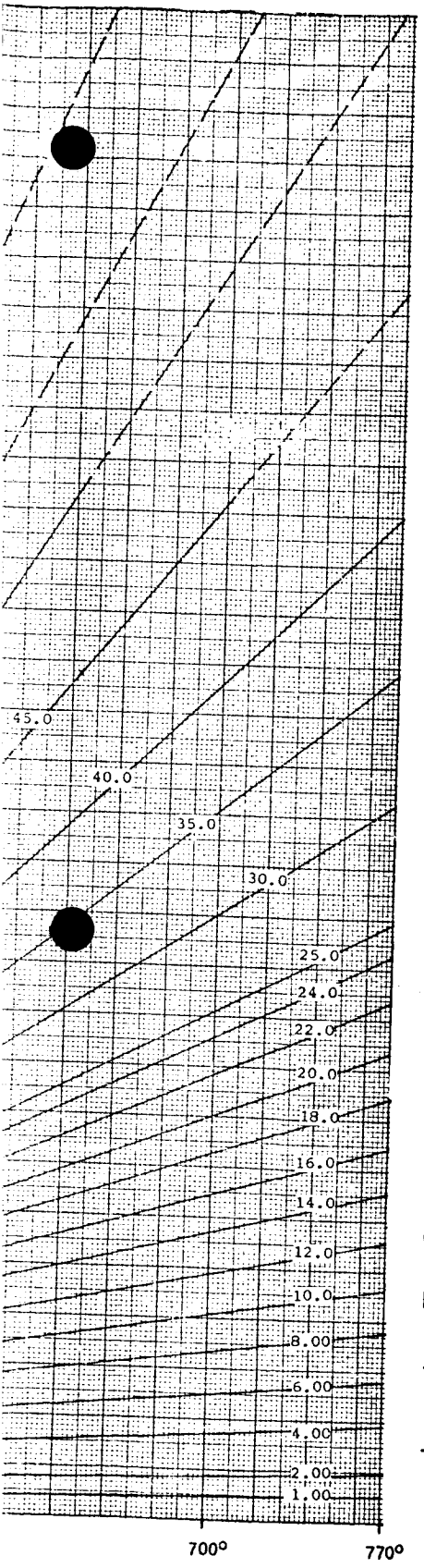
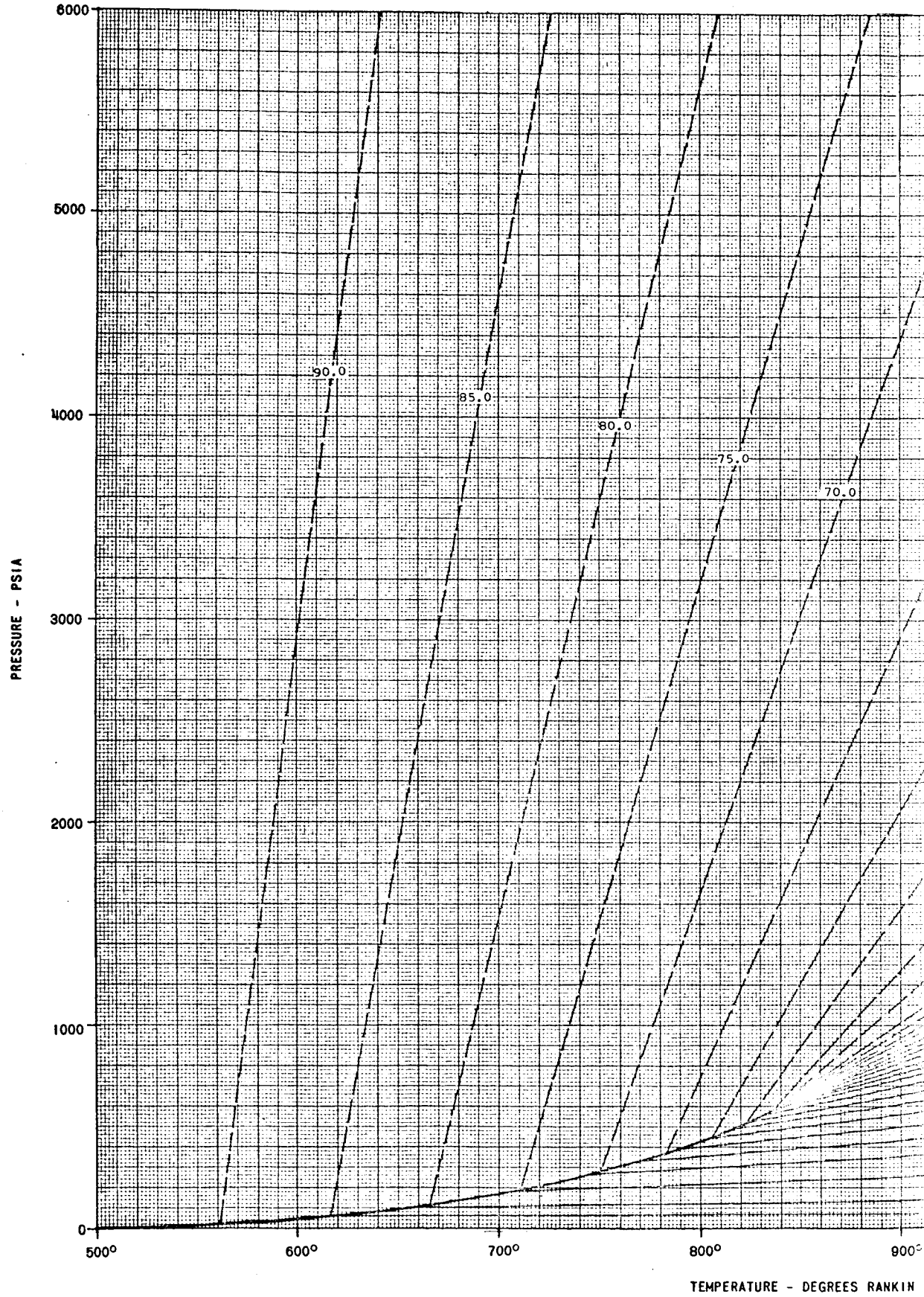


FIG. XV-20-2
FREON 14 (CF_4)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

——— COMMONLY ACCEPTED DATA

— — EXTRAPOLATED OR UNCONFIRMED DATA


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
90.0
85.0
80.0
75.0
70.0
500°
600°
700°
800°
900°
TEMPERATURE - DEGREES RANKIN

XV-17-27

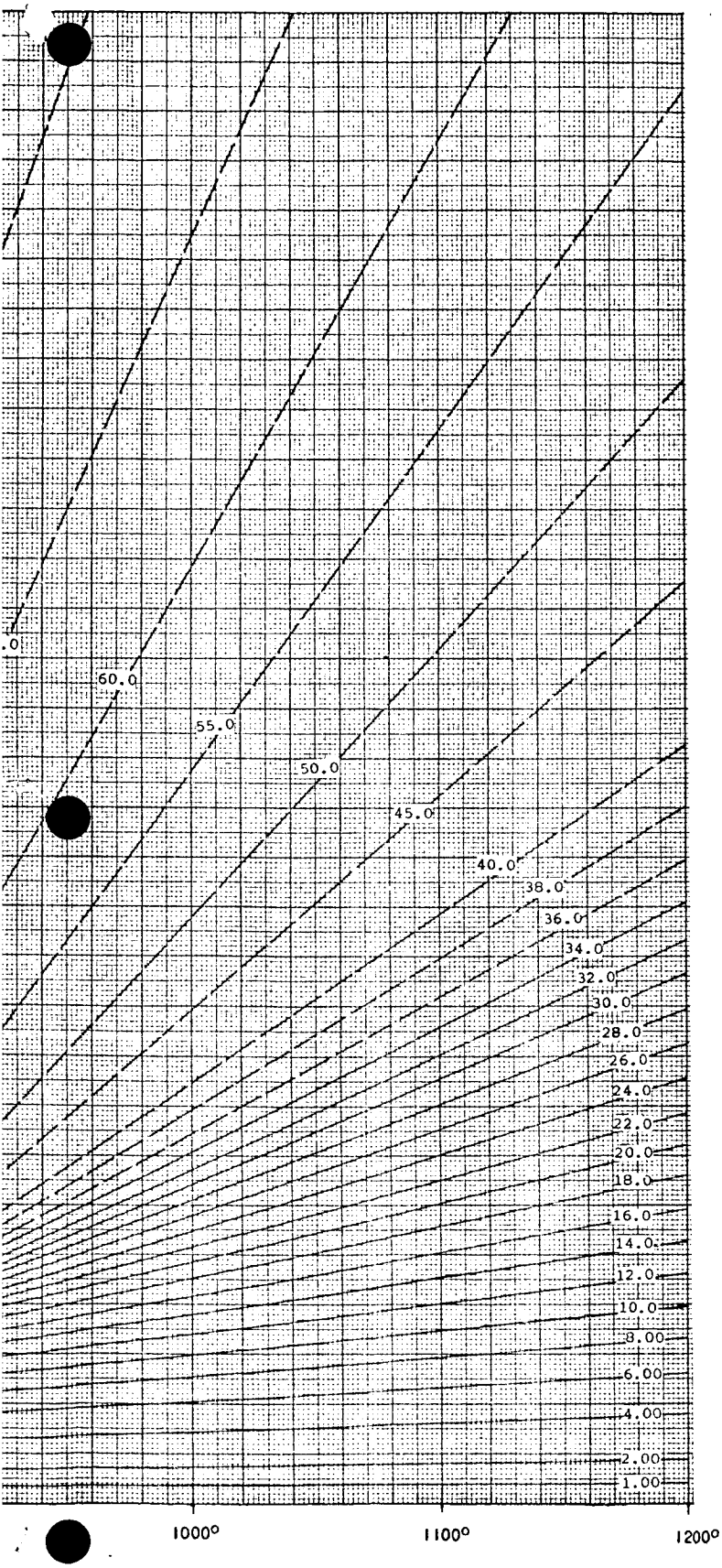


FIG. XV-17-2
FREON 11 (CCl_3F)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

COMMONLY ACCEPTED
DATA

EXTRAPOLATED OR
UNCONFIRMED DATA

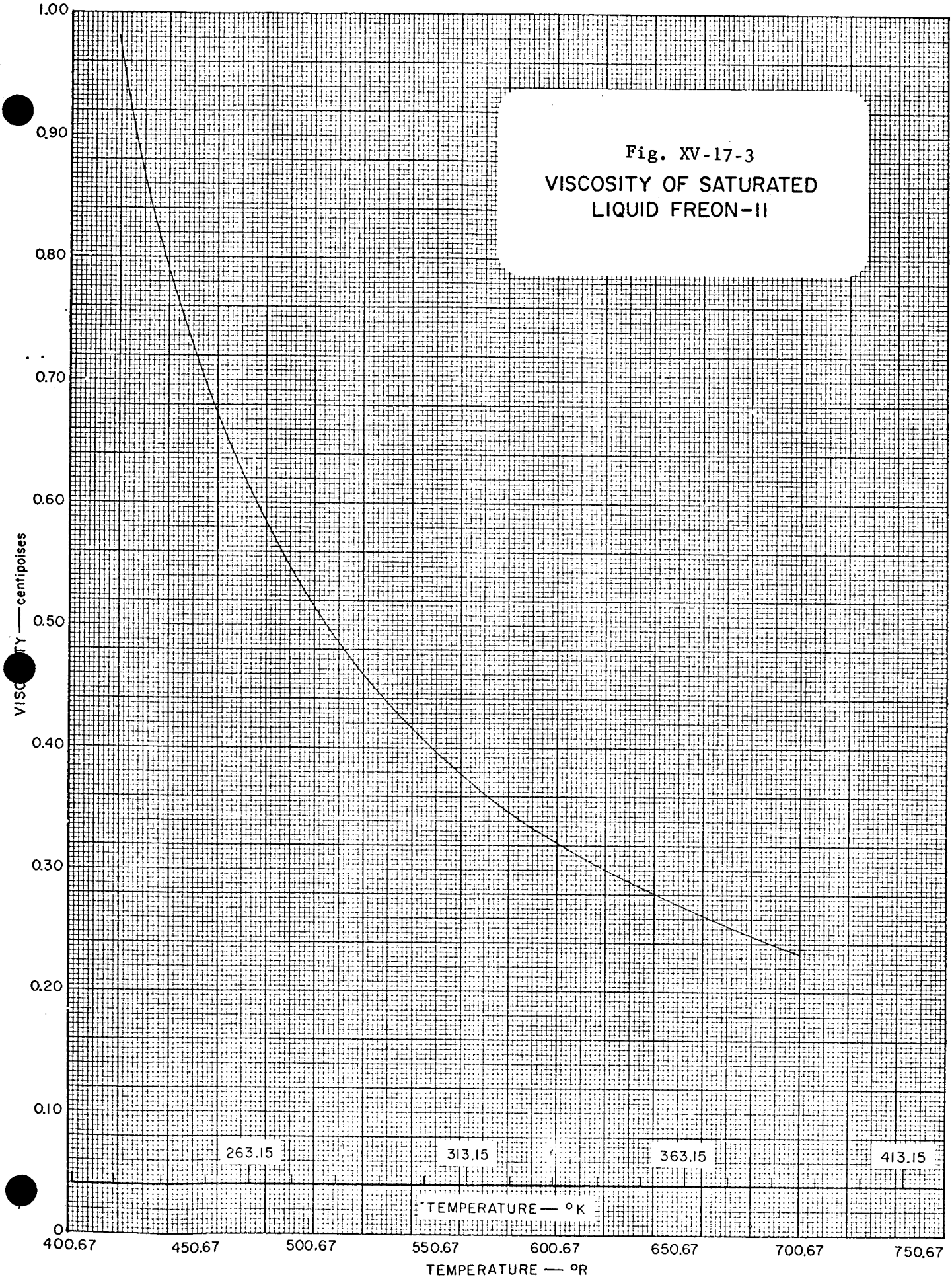


Fig. XV-17-3
VISCOSITY OF SATURATED
LIQUID FREON-11
VISCOSITY — centipoises
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
263.15
313.15
363.15
413.15
TEMPERATURE — °K
400.67
450.67
500.67
550.67
600.67
650.67
700.67
750.67
TEMPERATURE — °R

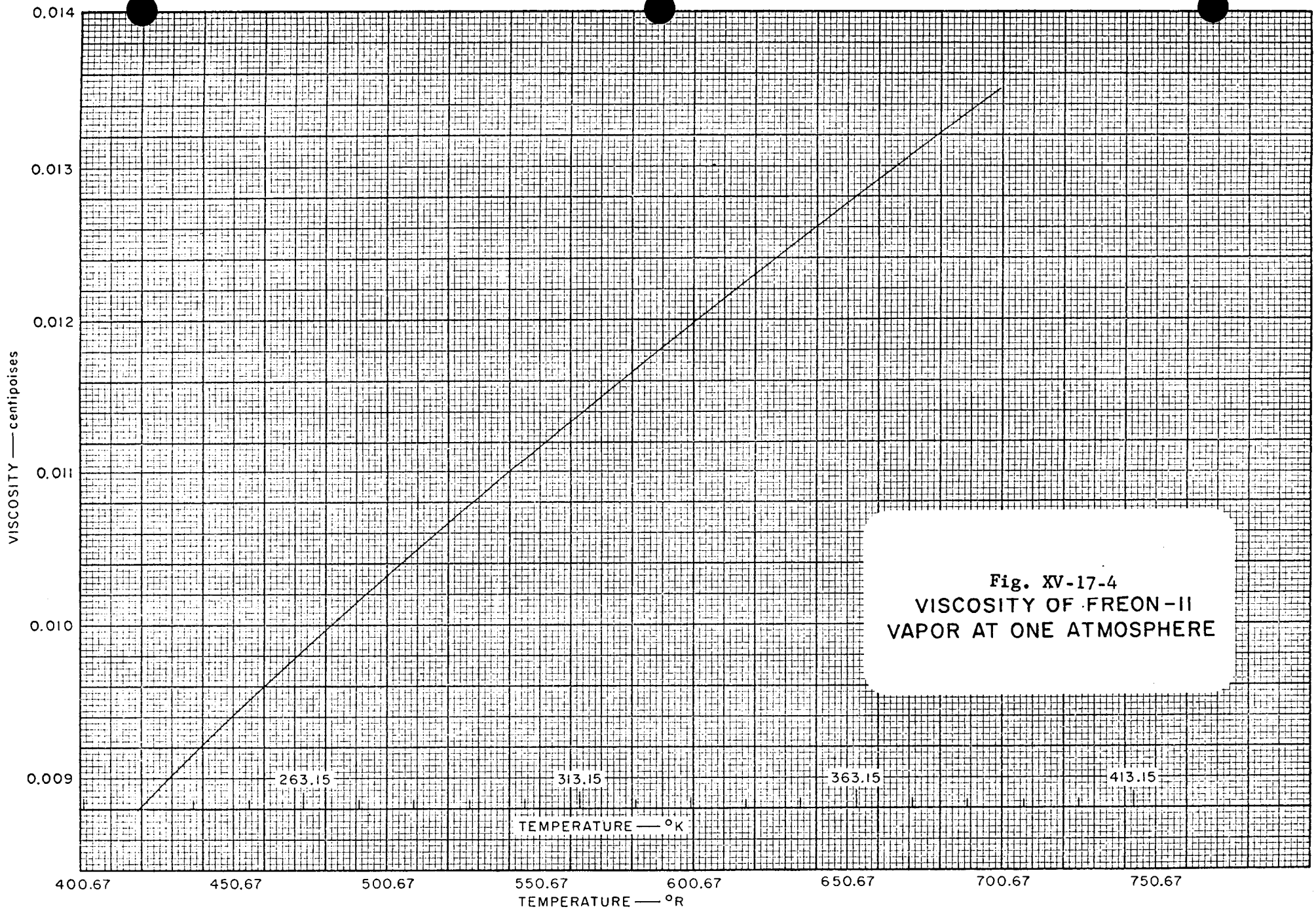


Fig. XV-17-4
VISCOSITY OF FREON-11
VAPOR AT ONE ATMOSPHERE

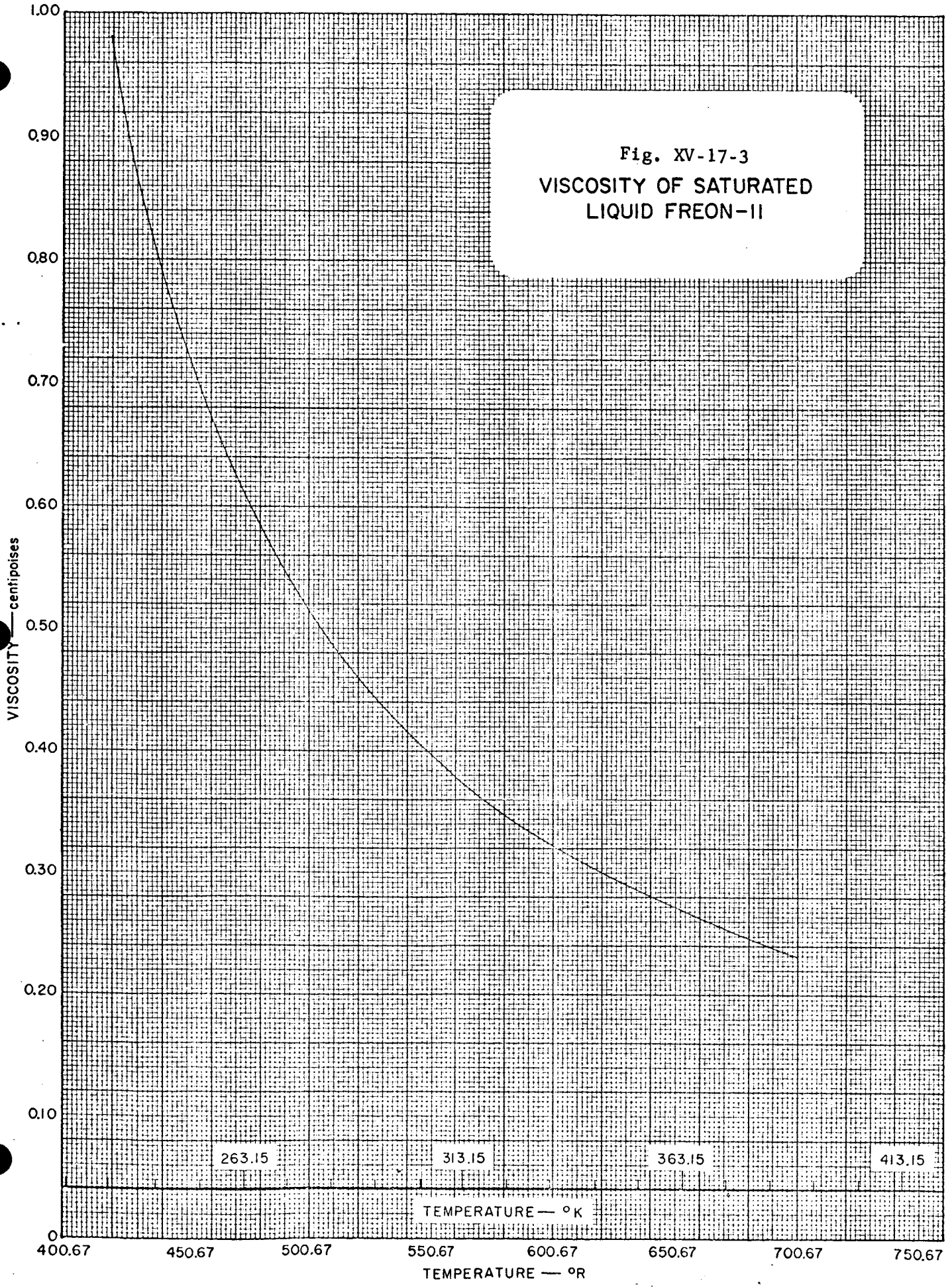


Fig. XV-17-3
VISCOSITY OF SATURATED
LIQUID FREON-11
VISCOSITY — centipoises
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
263.15
313.15
363.15
413.15
TEMPERATURE — °K
400.67
450.67
500.67
550.67
600.67
650.67
700.67
750.67
TEMPERATURE — °R

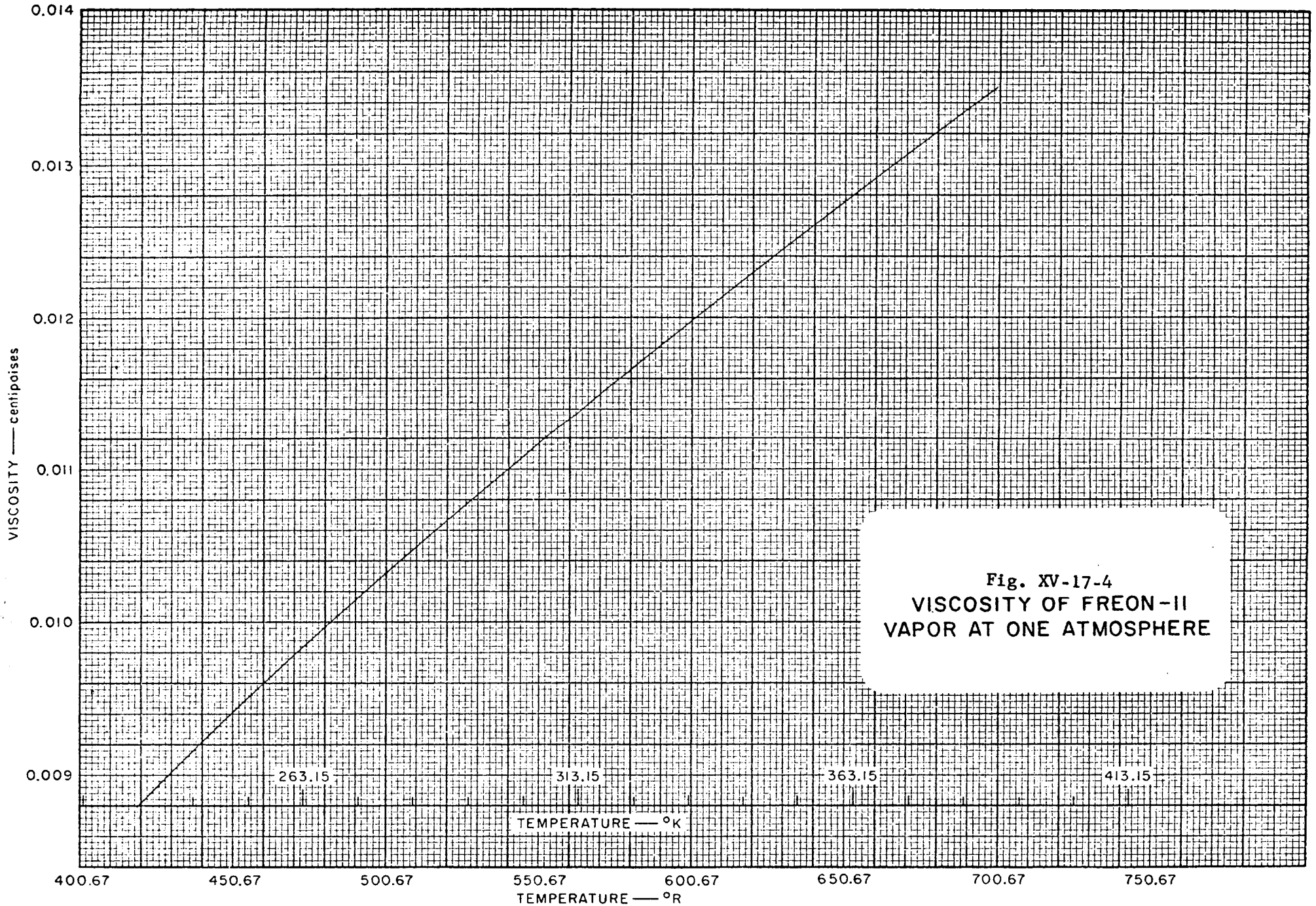


Fig. XV-17-4
VISCOSITY OF FREON-11
VAPOR AT ONE ATMOSPHERE

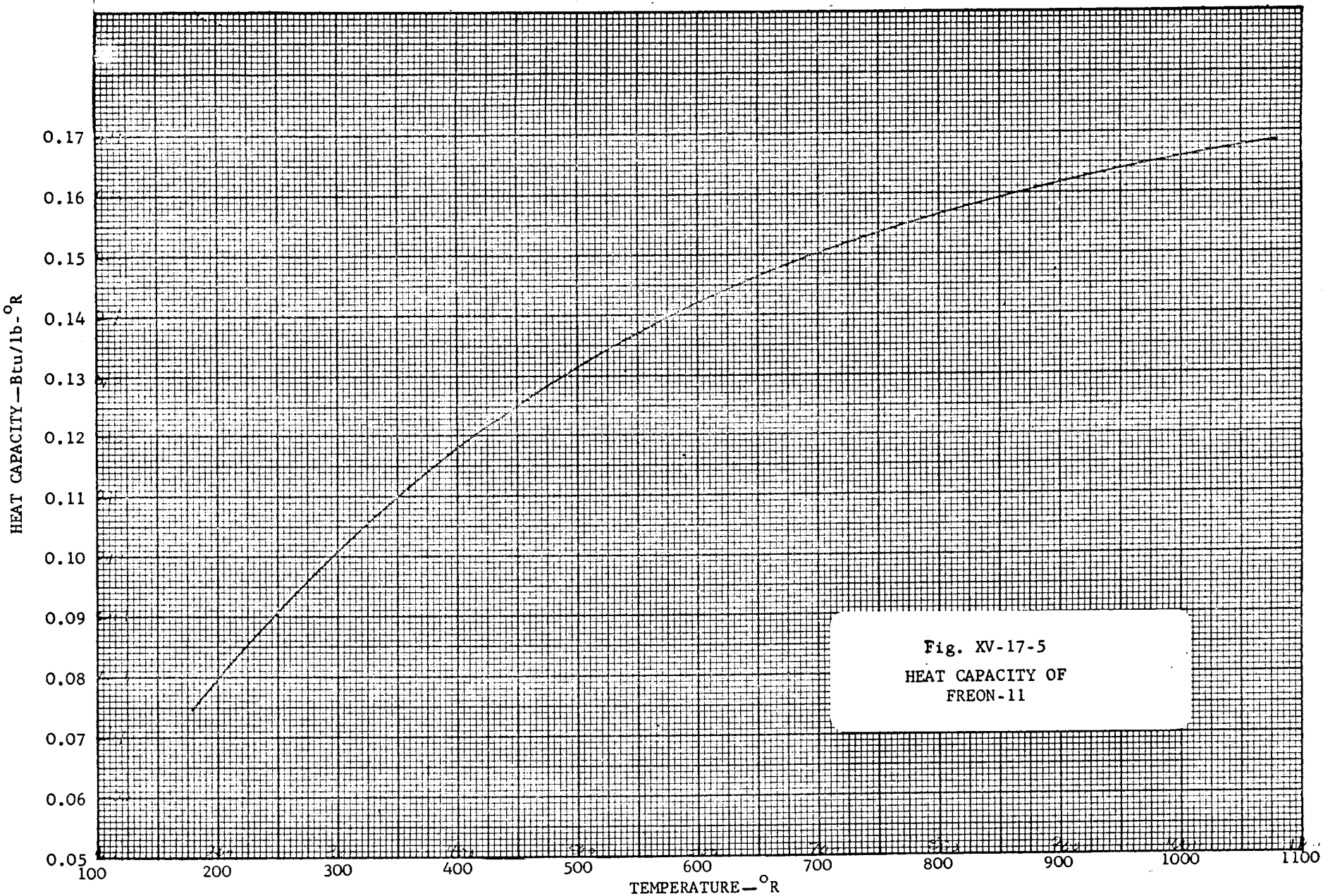


Fig. XV-17-5
HEAT CAPACITY OF
FREON-11

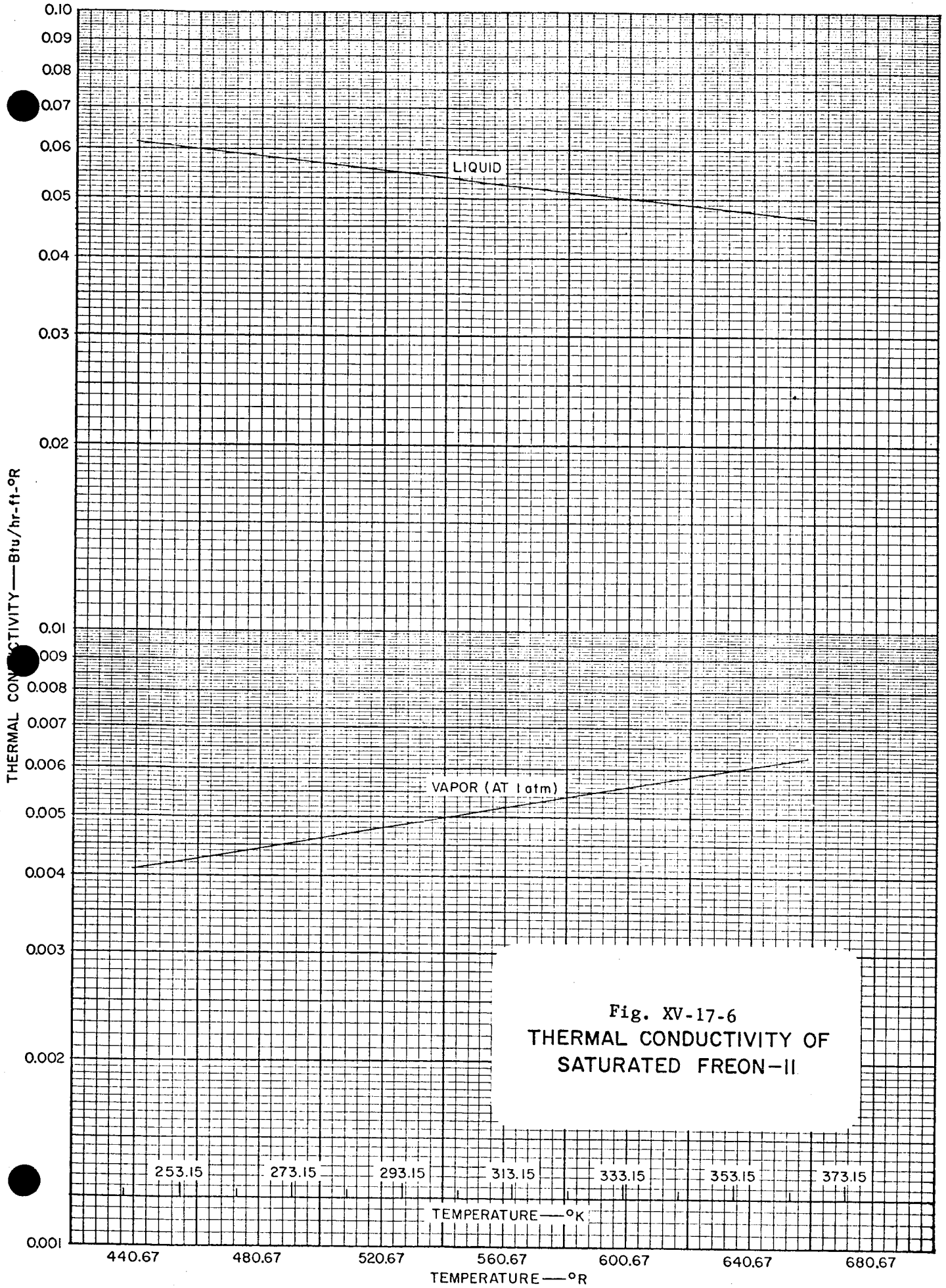


Fig. XV-17-6
THERMAL CONDUCTIVITY OF SATURATED FREON-11

XV-17 FREON-11 REFERENCES

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2. Du Pont de Nemours, E.I. and Co. Bull. B-9A.
3. Du Pont de Nemours, E.I. and Co. Bull. B-10A.
4. Gelles, E. and Pitzer, K.S. J. ACS 75, p. 5259, 1953.
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7. Properties of commonly used refrigerants. Air Conditioning and Refrigerants Institute, Wash., D.C. 1957.

Table XV-18-1

PHYSICAL CONSTANTS

OF

FREON-12

		REF.
Molecular Weight	120.93	6
Boiling Point @ 1 atm	-21.62°F	6
Freezing Point @ 1 atm	-252°F	6
Specific Volume @ 70°F, 1 atm	3.1306 cu ft/lb	6
Vapor Pressure @ 70°F	84.89 psia	6
Specific Gravity, (Air = 1)	4.2	6
Density		
Liquid @ 86°F	80.6596 lb/cu ft	6
Gas @ b.p.	0.3952 lb/cu ft	6
Critical Temperature	233.6°F	6
Critical Pressure	596.9 psia	6
Critical Density	34.836 lb/cu ft	6
Latent Heat of Vaporization @ b.p.	71.04 Btu/lb	6
Latent Heat of Fusion		
Specific Heat of Gas		
c_p @ 86°F, 1 atm	0.145 Btu/lb-°F	6
c_v @ 86°F, 1 atm	0.1275 Btu/lb-°F	
Specific Heat Ratio, c_p/c_v	1.137	6
Thermal Conductivity @ 86°F, 1 atm	0.00557 Btu/hr-ft-°F	6
Viscosity		
Liquid @ 86°F	1.69×10^{-4} lb/ft-sec	6
Gas @ 86°F	8.53×10^{-6} lb/ft-sec	6
Solubility in Water @ 77°F, 1 atm	0.028% (by wt.)	6
Surface Tension @ 77°F	6.167×10^{-4} lb/ft	6

Table XV-18-1.1

SOME VALUES OF THE GAS CONSTANT, R, FOR FREON-12

(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.678547	0.701093	515.696	9.97197
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0108691	0.0112303	8.26058	0.159734
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.376971	0.389496	286.498	5.53998
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00603844	0.00623906	4.58921	0.0887406
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-18-2

VAPOR PRESSURE OF FREON-12 (Ref. 2)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
170.93	307.67	0.1380	249.82	449.67	19.19
172.04	309.67	0.1536	255.37	459.67	23.85
177.59	319.67	0.2562	260.93	469.67	29.34
183.15	329.67	0.4122	266.48	479.67	35.74
188.70	339.67	0.6419	272.04	489.67	43.15
194.26	349.67	0.9703	283.15	509.67	61.40
199.82	359.67	1.428	294.26	529.67	84.89
205.37	369.67	2.051	305.37	549.67	114.5
210.93	379.67	2.881	316.48	569.67	151.1
216.48	389.67	3.965	327.67	589.67	195.7
222.04	399.67	5.358	344.26	619.67	279.8
227.59	409.67	7.117	360.93	649.67	388.0
233.15	419.67	9.308	372.04	669.67	475.5
238.70	429.67	12.00	383.15	689.67	577.0
244.26	439.67	15.27			

(See Figure XV-18-1)

Table XV-18-3

DENSITY OF FREON-12 (Ref. 2)

DENSITY-lb/ft^3									
PRESSURE psia / TEMP. °R	100	200	400	600	1000	1400	2000	4000	6000
440	(92.6)	(92.8)	(92.9)	(93.1)	(93.6)	(94.0)	(94.5)	-	-
480	(88.5)	(88.6)	(89.0)	(89.3)	(89.8)	(90.3)	(91.0)	(93.0)	(94.8)
520	(83.9)	(84.1)	(94.5)	(85.0)	(85.7)	(86.3)	(87.1)	(89.7)	(91.7)
560	2.32	(79.0)	(79.6)	(80.1)	(81.1)	(82.0)	(83.2)	(86.3)	(88.7)
600	2.09	4.86	(73.4)	(74.4)	(75.9)	(77.3)	(78.8)	(82.8)	(85.6)
640	1.91	4.25	(65.4)	(67.2)	(70.0)	(71.9)	(74.1)	(79.3)	(82.6)
680	1.77	3.83	9.69	(55.0)	(62.0)	(65.6)	(69.0)	(75.6)	(79.6)
720	1.65	3.51	8.22	16.15	(50.5)	(57.6)	(63.3)	(71.8)	(76.5)
760	1.55	3.25	7.31	12.81	(34.0)	(48.1)	(56.9)	(68.0)	(73.5)
800	1.46	3.04	6.65	11.11	(25.0)	(39.3)	(50.4)	(64.3)	(70.5)
840	(1.4)	2.86	6.14	9.97	(19.3)	(32.6)	(44.5)	(60.5)	(67.5)
880	(1.4)	2.70	5.72	9.13	(16.6)	(27.4)	(39.5)	(57.1)	(64.7)
920	(1.3)	(2.6)	5.37	8.46	(15.0)	(23.0)	(35.4)	(53.6)	(62.1)
960	(1.3)	(2.5)	(4.8)	7.91	(13.7)	(19.9)	(31.9)	(50.5)	(59.4)

(See Figure XV-18-2)

NOTE: (__) Data Extrapolated.

Table XV-18-4

VISCOSITY OF SATURATED LIQUID FREON-12 (Ref. 4)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centi-poises	°K	°R	centi-poises
233.15	419.67	0.423	344.26	619.67	0.214
244.26	439.67	0.371	355.37	639.67	0.207
255.37	459.67	0.335	366.48	659.67	0.200
266.48	479.67	0.308			
277.59	499.67	0.286			
288.71	519.67	0.269			
299.82	539.67	0.255			
310.93	559.67	0.242			
322.04	579.67	0.232			
333.15	599.67	0.222			

(See Figure XV-18-3)

Table XV-18-5

VISCOSITY OF FREON-12 VAPOR AT ONE ATMOSPHERE (Ref. 4)

TEMPERATURE		ABSOLUTE VISCOSITY	TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	centi-poises	°K	°R	centi-poises
233.15	419.67	0.0106	344.26	619.67	0.0138
244.26	439.67	0.0109	355.37	639.67	0.0140
255.37	459.67	0.0113	366.48	659.67	0.0143
266.48	479.67	0.0116	377.59	679.67	0.0146
277.59	499.67	0.0119	388.71	699.67	0.0149
288.71	519.67	0.0123			
299.82	539.67	0.0126			
310.93	559.67	0.0129			
322.04	579.67	0.0132			
333.15	599.67	0.0135			

(See Figure XV-18-4)

Table XV-18-6

HEAT CAPACITY OF FREON-12 (Ref. 5)

TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R
100	180	0.0782
150	270	0.0974
200	360	0.1154
250	450	0.1306
298.16	536.7	0.1429
300	540	0.1433
400	720	0.1627
500	900	0.1760
600	1080	0.1850

(See Figure XV-18-5)

Table XV-18-7

THERMAL CONDUCTIVITY OF SATURATED FREON-12 (Ref. 3)

TEMPERATURE		THERMAL CONDUCTIVITY-Btu/hr-ft-°R	
°K	°R	Liquid	Vapor (at 1 atm)
253.15	455.67	0.051	
293.15	527.67	0.042	
303.15	545.67		0.00591
363.15	653.67		0.00738

(See Figure XV-18-8)

Table XV-18-8

THERMAL CONDUCTIVITY OF LIQUID FREON-12 (Ref. 7)

TEMPERATURE		THERMAL CONDUCTIVITY
°F	°R	Btu/hr-ft-°R
0	459.69	0.060
50	509.69	0.053
100	559.69	0.047

(See Figure XV-18-9)

Table XV-18-9

SELECTED VALUES OF PROPERTIES OF SATURATED VAPOR OF FREON-12 (Ref. 8)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-$^\circ$R	
$^\circ$R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
309.69	0.15359	0.0095822	178.65	104.36	0.005598	-22.697	83.534	60.837	-0.062619	0.20711
319.69	0.25623	0.0096579	110.46	103.54	0.009053	-20.652	82.548	61.896	-0.056123	0.20208
329.69	0.41224	0.0097359	70.730	102.71	0.014138	-18.609	81.577	62.968	-0.049830	0.19760
339.69	0.64190	0.0098163	46.741	101.87	0.021395	-16.565	80.617	64.052	-0.043723	0.19359
349.69	0.97034	0.0098992	31.777	101.02	0.031470	-14.518	79.663	65.145	-0.037786	0.19002
359.69	1.4280	0.0099847	22.164	100.15	0.045119	-12.466	78.714	66.248	-0.032005	0.18683
369.69	2.0509	0.010073	15.821	99.274	0.063207	-10.409	77.764	67.355	-0.026367	0.18398
379.69	2.8807	0.010164	11.533	98.382	0.086708	- 8.3451	76.812	68.467	-0.020862	0.18143
389.69	3.9651	0.010259	8.5687	97.475	0.11670	- 6.2730	75.853	69.580	-0.015481	0.17916
399.69	5.3575	0.010357	6.4774	96.553	0.15438	- 4.1919	74.885	70.693	-0.010214	0.17714
409.69	7.1168	0.010459	4.9742	95.616	0.20104	- 2.1011	73.906	71.805	-0.005056	0.17533
419.69	9.3076	0.010564	3.8750	94.661	0.25806	0.0000	72.913	72.913	0.000000	0.17373
429.69	11.999	0.010674	3.0585	93.690	0.32696	2.1120	71.903	74.015	0.004961	0.17229
439.69	15.267	0.010788	2.4429	92.699	0.40934	4.2357	70.874	75.110	0.009831	0.17102
449.69	19.189	0.010906	1.9727	91.689	0.50693	6.3716	69.824	76.196	0.014617	0.16989
459.69	23.849	0.011030	1.6089	90.659	0.62156	8.5207	68.750	77.271	0.019323	0.16888
469.69	29.335	0.011160	1.3241	89.606	0.75523	10.684	67.651	78.335	0.023954	0.16798
479.69	35.736	0.011296	1.0988	88.529	0.91006	12.863	66.522	79.385	0.028515	0.16719
489.69	43.148	0.011438	0.91880	87.426	1.0884	15.058	65.361	80.419	0.033013	0.16648
499.69	51.667	0.011588	.0.77357	86.296	1.2927	17.273	64.163	81.436	0.037453	0.16586
509.69	61.394	0.011746	0.65537	85.136	1.5258	19.507	62.926	82.433	0.041839	0.16530

Table XV-18-9 (contd)

SELECTED VALUES OF PROPERTIES OF SATURATED VAPOR OF FREON-12 (Ref. 8)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-$^\circ$R	
$^\circ$R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
519.69	72.433	0.011913	0.55839	83.944	1.7909	21.766	61.643	83.409	0.046180	0.16479
529.69	84.888	0.012089	0.47818	82.717	2.0913	24.050	60.309	84.359	0.050482	0.16434
539.69	98.870	0.012277	0.41135	81.450	2.4310	26.365	58.917	85.282	0.054751	0.16392
549.69	114.49	0.012478	0.35529	80.142	2.8146	28.713	57.461	86.174	0.058997	0.16353
559.69	131.86	0.012693	0.30794	78.785	3.2474	31.100	55.929	87.029	0.063227	0.16315
569.69	151.11	0.012924	0.26769	77.376	3.7357	33.531	54.313	87.844	0.067451	0.16279
579.69	172.35	0.013174	0.23326	75.906	4.2870	36.013	52.597	88.610	0.071680	0.16241
589.69	195.71	0.013447	0.20364	74.367	4.9107	38.553	50.768	89.321	0.075927	0.16202
599.69	221.32	0.013746	0.17799	72.748	5.6184	41.162	48.805	89.967	0.080205	0.16159
609.69	249.31	0.014078	0.15564	71.035	6.4252	43.850	46.684	90.534	0.084531	0.16110
619.69	279.82	0.014449	0.13604	69.209	7.3509	46.633	44.373	91.006	0.088927	0.16053
629.69	313.00	0.014871	0.11873	67.244	8.4228	49.529	41.830	91.359	0.093418	0.15985
639.69	349.00	0.015360	0.10330	65.102	9.6802	52.562	38.999	91.561	0.098039	0.15900
649.69	387.98	0.015942	0.89418	62.728	11.183	55.769	35.792	91.561	0.10284	0.15793
659.69	430.09	0.016659	0.076728	60.026	13.033	59.203	32.075	91.278	0.10789	0.15651
669.69	475.52	0.017601	0.064843	56.816	15.422	62.959	27.599	90.558	0.11332	0.15453
679.69	524.43	0.018986	0.053140	52.670	18.818	67.246	21.790	89.036	0.11943	0.15149
689.69	577.03	0.021854	0.039435	45.758	25.358	72.893	12.229	85.122	0.12739	0.14512
693.29 (Critical)	596.9	0.02870	0.02870	34.84	34.84	78.86	0	78.86	0.1359	0.1359

V = volume in cu-ft/lb
H = enthalpy in btu/lb
S = entropy in btu/lb-°R
(saturation properties in parentheses)

Table XV-18-10.1

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 1, 2, 3 psia (Ref. 2)

TEMPERATURE	1 psia (sat'n temp. 350.45°R)			2 psia (sat'n temp. 368.98°R)			3 psia (sat'n temp. 380.93°R)		
°R	V	H	S	V	H	S	V	H	S
(at sat'n)	(30.896)	(65.229)	(0.18977)						
349.69	...	...	...						
359.69	31.730	66.303	0.19279	(16.195)	(67.276)	(0.18417)	(11.106)	(68.604)	(0.18114)
369.69	32.631	67.482	0.19602	16.228	67.361	0.18440	...	...	...
379.69	33.531	68.679	0.19922	16.684	68.567	0.18762	...	...	...
389.69	34.429	69.892	0.20237	17.139	69.788	0.19079	11.375	69.683	0.18394
399.69	35.327	71.123	0.20549	17.593	71.026	0.19393	11.681	70.928	0.18709
409.69	36.223	72.370	0.20857	18.046	72.279	0.19703	11.986	72.188	0.19021
419.69	37.119	73.633	0.21162	18.498	73.549	0.20009	12.290	73.463	0.19328
429.69	38.014	74.913	0.21463	18.949	74.834	0.20311	12.594	74.754	0.19632
439.69	38.908	76.208	0.21761	19.400	76.134	0.20611	12.897	76.059	0.19932
449.69	39.802	77.519	0.22056	19.850	77.449	0.20906	13.199	77.379	0.20229
459.69	40.695	78.845	0.22347	20.299	78.780	0.21199	13.500	78.714	0.20523
469.69	41.587	80.186	0.22636	20.748	80.125	0.21488	13.802	80.063	0.20813
479.69	42.480	81.542	0.22922	21.197	81.484	0.21775	14.102	81.426	0.21100
489.69	43.372	82.912	0.23204	21.645	82.858	0.22058	14.403	82.803	0.21384
499.69	44.263	84.297	0.23484	22.093	84.245	0.22339	14.703	84.194	0.21665
509.69	45.154	85.695	0.23761	22540	85.646	0.22616	15.002	85.598	0.21944

Table XV-18-10.1 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 1, 2, 3 psia

TEMPERATURE	1 psia (sat'n temp. 350.45°R)			2 psia (sat'n temp. 368.98°R)			3 psia (sat'n temp. 380.93°R)		
°R	V	H	S	V	H	S	V	H	S
519.69	46.045	87.107	0.24036	22.988	87.061	0.22891	15.302	87.015	0.22219
529.69	46.936	88.533	0.24307	23.435	88.489	0.23163	15.601	88.445	0.22492
539.69	47.826	89.971	0.24576	23.881	89.930	0.23433	15.900	89.889	0.22762
549.69	48.716	91.423	0.24843	24.328	91.384	0.23700	16.198	91.345	0.23029
559.69	49.606	92.887	0.25107	24.774	92.850	0.23964	16.497	92.813	0.23293
569.69	50.496	94.364	0.25368	25.220	94.329	0.24226	16.795	94.293	0.23556
579.69	51.386	95.853	0.25628	25.666	95.819	0.24485	17.093	95.785	0.23815
589.69	52.275	97.354	0.25884	26.112	97.322	0.24742	17.391	97.289	0.24073
599.69	53.165	98.867	0.26139	26.558	98.836	0.24997	17.689	98.805	0.24327
609.69	54.054	100.391	0.26391	27.003	100.361	0.25249	17.987	100.332	0.24580
619.69	54.943	101.926	0.26640	27.449	101.898	0.25499	18.284	101.869	0.24830
629.69	55.832	103.472	0.26888	27.894	103.445	0.25747	18.582	103.418	0.25078
639.69	56.721	105.030	0.27133	28.340	105.003	0.25992	18.879	104.977	0.25324
649.69				28.785	106.572	0.26236	19.176	106.547	0.25567
659.69				29.230	108.151	0.26477	19.473	108.127	0.25808

Table XV-18-10.2

PROPERTIES OF SUPER HEATED VAPOR OF FREON-12 AT 5, 10, 25 psia (Ref. 2)

TEMPERATURE	5 psia (sat'n temp. 397.34°R)			10 psia (sat'n temp. 422.46°R)			25 psia (sat'n temp. 461.89°R)		
°R	V	H	S	V	H	S	V	H	S
(at sat'n)	(6.9069)	(70.432)	(0.17759)						
389.69	...	...	...						
399.69	6.9509	70.729	0.17834						
409.69	7.1378	72.003	0.18149	(3.6246)	(73.219)	(0.17331)			
419.69	7.3239	73.291	0.18459	...	...	...			
429.69	7.5092	74.593	0.18766	3.6945	74.183	0.17557			
439.69	7.6938	75.909	0.19069	3.7906	75.526	0.17866			
449.69	7.8777	77.239	0.19368	3.8861	76.880	0.18171			
459.69	8.0611	78.582	0.19663	3.9809	78.246	0.18471	(1.5392)	(77.510)	(0.16867)
469.69	8.2441	79.939	0.19955	4.0753	79.624	0.18768	1.5714	78.635	0.17108
479.69	8.4265	81.309	0.20244	4.1691	81.014	0.19061	1.6125	80.088	0.17414
489.69	8.6086	82.693	0.20529	4.2626	82.415	0.19350	1.6531	81.547	0.17715
499.69	8.7903	84.090	0.20812	4.3556	83.828	0.19635	1.6932	83.012	0.18012
509.69	8.9717	85.500	0.21091	4.4484	85.252	0.19918	1.7329	84.485	0.18304
519.69	9.1528	86.922	0.21367	4.5408	86.689	0.20197	1.7723	85.965	0.18591
529.69	9.3336	88.358	0.21641	4.6329	88.136	0.20473	1.8114	87.453	0.18875
539.69	9.5142	89.806	0.21912	4.7248	89.596	0.20746	1.8502	88.950	0.19155
549.69	9.6945	91.266	0.22180	4.8165	91.067	0.21016	1.8888	90.455	0.19431
559.69	9.8747	92.738	0.22445	4.9079	92.548	0.21283	1.9271	91.968	0.19704

Table XV-18-10.2 (contd)

PROPERTIES OF SUPERHEAD VAPOR OF FREON-12 AT 5, 10, 25 psia

TEMPERATURE	5 psia (sat'n temp. 397.34°R)			10 psia (sat'n temp. 422.46°R)			25 psia (sat'n temp. 461.89°R)		
°R	V	H	S	V	H	S	V	H	S
569.69	10.055	94.222	0.22708	4.9992	94.042	0.21547	1.9653	93.490	0.19973
579.69	10.234	95.717	0.22968	5.0903	95.546	0.21809	2.0032	95.021	0.20240
589.69	10.414	97.224	0.23226	5.1812	97.061	0.22068	2.0410	96.561	0.20503
599.69	10.594	98.743	0.23481	5.2720	98.586	0.22325	2.0786	98.110	0.20763
609.69	10.773	100.272	0.23734	5.3627	100.123	0.22579	2.1161	99.667	0.21021
619.69	10.952	101.812	0.23985	5.4533	101.669	0.22830	2.1535	101.234	0.21276
629.69	11.131	103.363	0.24233	5.5437	103.226	0.23080	2.1908	102.809	0.21528
639.69	11.311	104.925	0.24479	5.6341	104.793	0.23326	2.2279	104.393	0.21778
649.69	11.489	106.497	0.24723	5.7243	106.370	0.23571	2.2650	105.986	0.22025
659.69	11.668	108.079	0.24964	5.8145	107.957	0.23813	2.3019	107.588	0.22269
669.69	11.847	109.670	0.25204	5.9046	109.553	0.24054	2.3388	109.198	0.22512
679.69	12.026	111.272	0.25441	5.9946	111.159	0.24291	2.3756	110.817	0.22752
689.69				6.0846	112.774	0.24527	2.4124	112.444	0.22989
699.69				6.1745	114.398	0.24761	2.4491	114.080	0.23225
709.69				6.2643	116.031	0.24993	2.4857	115.723	0.23458
719.69							2.5223	117.375	0.23689
729.69							2.5588	119.035	0.23918
739.69							2.5953	120.703	0.24145
749.69							2.6317	122.378	0.24370
759.69							2.6681	124.061	0.24593

Table XV-18-10.3

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 50, 100, 200 psia

TEMPERATURE	50 psia (sat'n temp. 497.84°R)			100 psia (sat'n temp. 540.45°R)			200 psia (sat'n temp. 591.43°R)		
°R	V	H	S	V	H	S	V	H	S
(at sat'n)	(0.79824)	(81.249)	(0.16597)						
499.69	.80248	81.540	.16655						
509.69	.82502	83.109	.16966						
519.69	.84713	84.676	.17271						
529.69	.86886	86.243	.17569	(0.40674)	(85.351)	(0.16389)			
539.69	.89025	87.811	.17862	...	...	...			
549.69	.91134	89.380	.18151	.41876	86.964	0.16685			
559.69	.93216	90.953	.18434	.43138	88.694	.16996			
569.69	.95275	92.529	.18713	.44365	90.410	.17300			
579.69	.97313	94.110	.18988	.45562	92.116	.17597	(0.19891)	(89.439)	(0.16195)
589.69	.99332	95.695	.19259	.46733	93.814	.17888	...	...	...
599.69	1.0133	97.286	.19527	.47881	95.507	.18172	.20579	91.137	.16480
609.69	1.0332	98.882	.19791	.49009	97.197	.18452	.21370	93.141	.16811
619.69	1.0529	100.485	.20051	.50118	98.884	.18726	.22121	95.100	.17130
629.69	1.0725	102.093	.20309	.51212	100.571	.18996	.22842	97.024	.17438
639.69	1.0920	103.708	.20563	.52291	102.257	.19262	.23535	98.921	.17737
649.69	1.1114	105.330	.20815	.53358	103.944	.19524	.24207	100.795	.18027
659.69	1.1307	106.958	.21064	.54413	105.633	.19782	.24860	102.652	.18311
669.69	1.1499	108.593	.21310	.55457	107.324	.20036	.25496	104.494	.18588
679.69	1.1690	110.235	.21553	.56492	109.018	.20287	.26117	106.325	.18860
689.69	1.1880	111.883	.21794	.57519	110.714	.20535	.26726	108.147	.19126
699.69	1.2070	113.539	.22032	.58538	112.415	.20780	.27323	109.962	.19387
709.69	1.2259	115.202	.22268	.59549	114.119	.21022	.27911	111.771	.19644

Table XV-18-10.3 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 50, 100, 200 psia

TEMPERATURE	50 psia (sat'n temp. 497.84°R)			100 psia (sat'n temp. 540.45°R)			200 psia (sat'n temp. 591.43°R)		
°R	V	H	S	V	H	S	V	H	S
719.69	1.2447	116.871	.22502	.60554	115.828	.21261	.28489	113.576	.19896
729.69	1.2636	118.547	.22733	.61553	117.540	.21497	.29060	115.378	.20145
739.69	1.2823	120.231	.22962	.62546	119.258	.21731	.29623	117.178	.20390
749.69	1.3010	121.921	.23189	.63534	120.980	.21962	.30180	118.977	.20632
759.69	1.3197	123.618	.23414	.64518	122.707	.22191	.30730	120.775	.20870
769.69	1.3383	125.321	.23637	.65497	124.439	.22417	.31275	122.574	.21105
779.69	1.3569	127.032	.23857	.66472	126.176	.22641	.31815	124.373	.21337
789.69	1.3754	128.749	.24076	.67444	127.917	.22863	.32350	126.173	.21567
799.69				.68411	129.665	.23083	.32881	127.974	.21793
809.69				.69376	131.417	.23301	.33408	129.778	.22017
819.69				.70338	133.174	.23517	.33932	131.583	.22239
829.69				.71296	134.937	.23730	.34452	133.392	.22458
839.69							.34969	135.202	.22675
849.69							.35483	137.016	.22890
859.69							.35994	138.832	.23102
869.69							.36503	140.652	.23313
879.69							.37010	142.475	.23521

Table XV-18-10.4

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 300, 400, 500 psia (Ref. 2)

TEMPERATURE	300 psia (sat'n temp. 625.87°R)			400 psia (sat'n temp. 652.62°R)			500 psia (sat'n temp. 674.79°R)		
°R	V	H	S	V	H	S	V	H	S
(at sat'n)	(0.12510)	(91.240)	(0.16012)						
619.69	...	...	...						
629.69	.12794	92.187	.16163	(0.085587)	(91.513)	(0.15755)			
639.69	.13482	94.556	.16537	...	...	...			
649.69	.14111	96.808	.16886	...	...	...			
659.69	.14697	98.975	.17217	0.091005	93.718	0.16092			
669.69	.15249	101.080	.17534	0.097497	96.500	0.16510	(0.058917)	(89.924)	(0.15317)
679.69	.15774	103.136	.17838	0.10316	99.046	0.16888	0.064207	92.397	0.15683
689.69	.16277	105.153	.18133	0.10828	101.443	0.17238	0.071775	96.143	0.16230
699.69	.16761	107.140	.18419	0.11300	103.735	0.17568	0.077620	99.218	0.16672
709.69	.17230	109.102	.18697	0.11743	105.950	0.17882	0.082606	101.970	0.17063
719.69	.17685	111.043	.18969	0.12163	108.105	0.18183	0.087054	104.526	0.17421
729.69	.18129	112.968	.19235	0.12564	110.214	0.18475	0.091128	106.949	0.17755
739.69	.18562	114.879	.19495	0.12949	112.286	0.18756	0.094923	109.277	0.18072
749.69	.18986	116.779	.19750	0.13320	114.327	0.19031	0.098499	111.531	0.18375
759.69	.19402	118.670	.20000	0.13680	116.343	0.19298	0.10190	113.729	0.18666
769.69	.19811	120.553	.20247	0.14030	118.339	0.19559	0.10516	115.882	0.18947
779.69	.20214	122.430	.20489	0.14372	120.318	0.19814	0.10829	117.997	0.19221
789.69	.20610	124.302	.20728	0.14705	122.282	0.20065	0.11132	120.083	0.19486
799.69	.21002	126.171	.20963	0.15032	124.235	0.20310	0.11426	122.143	0.19746
809.69	.21388	128.036	.21195	0.15353	126.177	0.20552	0.11712	124.183	0.19999

Table XV-18-10.4 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 at 300, 400, 500 psia

TEMPERATURE	300 psia (sat'n temp. 625.87°R)			400 psia (sat'n temp. 652.62°R)			500 psia (sat'n temp. 674.79°R)		
°R	V	H	S	V	H	S	V	H	S
819.69	.21770	129.900	.21423	0.15668	128.112	0.20789	0.11992	126.205	0.20247
829.69	.22148	131.762	.21649	0.15979	130.039	0.21023	0.12265	128.212	0.20491
839.69	.22522	133.624	.21872	0.16285	131.961	0.21253	0.12533	130.207	0.20730
849.69	.22893	135.485	.22092	0.16587	133.878	0.21480	0.12796	132.191	0.20965
859.69	.23260	137.346	.22310	0.16885	135.792	0.21704	0.13054	134.166	0.21196
869.69	.23625	139.208	.22526	0.17179	137.703	0.21925	0.13308	136.134	0.21423
879.69	.23987	141.071	.22739	0.17471	139.612	0.22143	0.13559	138.096	0.21648
889.69	.24346	142.935	.22949	0.17759	141.519	0.22359	0.13807	140.052	0.21869
899.69	.24703	144.800	.23158	0.18045	143.424	0.22572	0.14051	142.004	0.22087
909.69	.25058	146.667	.23364	0.18328	145.330	0.22782	0.14292	143.952	0.22302
919.69				0.18609	147.235	0.22991	0.14531	145.898	0.22515
929.69				0.18888	149.140	0.23197	0.14768	147.841	0.22725
939.69							0.15002	149.782	0.22933
949.69							0.15234	151.723	0.23138
959.69							0.15464	153.662	0.23341
969.69							0.15692	155.601	0.23542

Table 18-10.5

PROPERTIES OF SUPERHEATED VAPOR OF FREON-12 AT 600 psia (Ref. 2)

TEMPERATURE	600 psia (sat'n temp. ...)		
°R	V	H	S
(sat'n temp.)	...	...	...
699.69	0.047488	91.024	0.15335
709.69	0.056059	96.105	0.16057
719.69	0.061922	99.741	0.16566
729.69	0.066700	102.837	0.16993
739.69	0.070859	105.637	0.17374
749.69	0.074605	108.249	0.17725
759.69	0.078059	110.729	0.18053
769.69	0.081285	113.111	0.18365
779.69	0.084333	115.420	0.18663
789.69	0.087236	117.669	0.18950
799.69	0.090017	119.871	0.19227
809.69	0.092697	122.035	0.19496
819.69	0.095289	124.167	0.19757
829.69	0.097805	126.272	0.20013
839.69	0.10025	128.355	0.20262
849.69	0.10264	130.419	0.20507
859.69	0.10498	132.466	0.20746
869.69	0.10727	134.500	0.20981
879.69	0.10952	136.523	0.21213
889.69	0.11173	138.535	0.21440
899.69	0.11391	140.539	0.21664
909.69	0.11605	142.536	0.21885
919.69	0.11816	144.526	0.22102
929.69	0.12025	146.512	0.22317
939.69	0.12231	148.493	0.22529
949.69	0.12435	150.470	0.22738
959.69	0.12637	152.444	0.22945
969.69	0.12837	154.416	0.23150

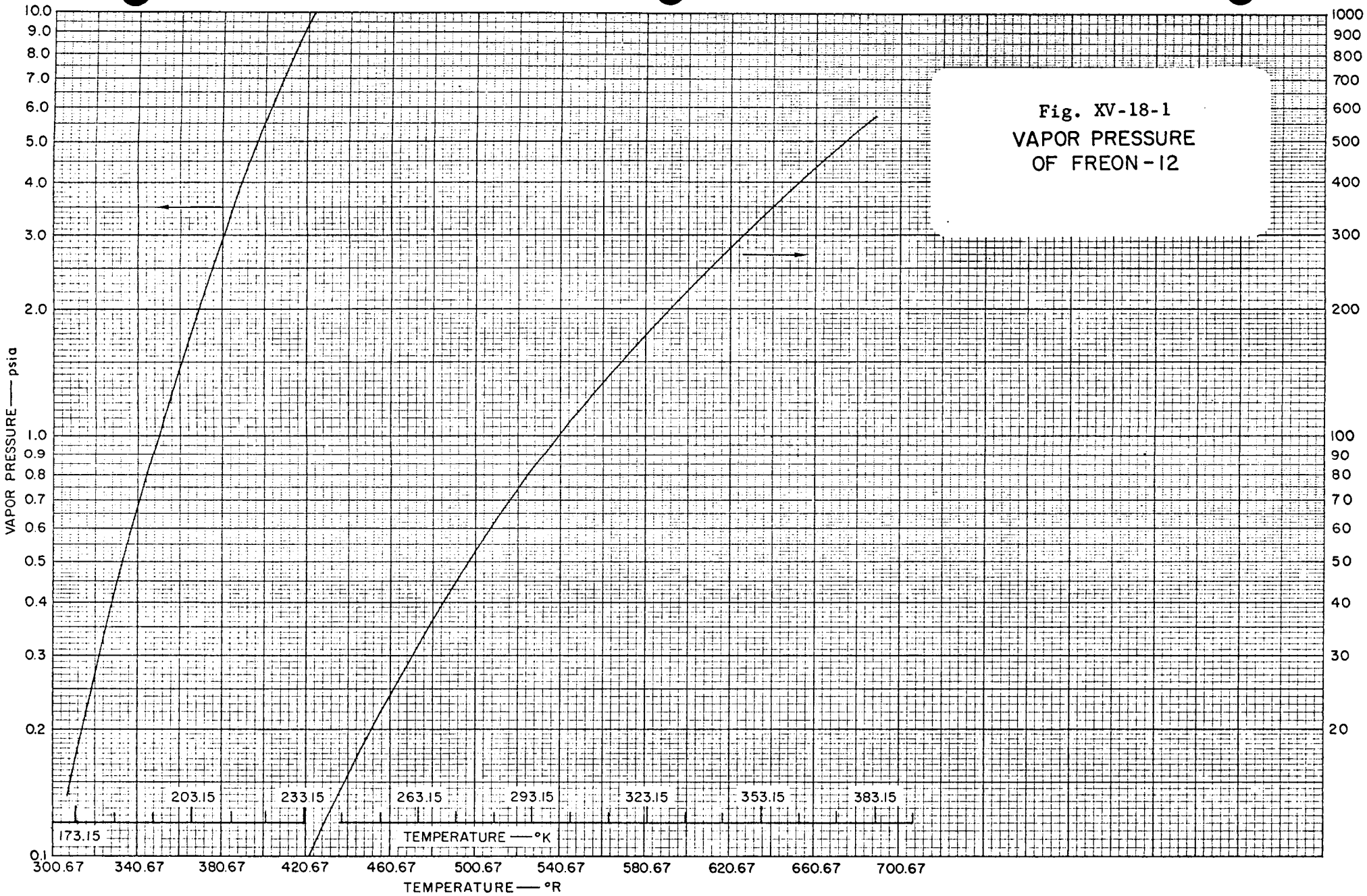
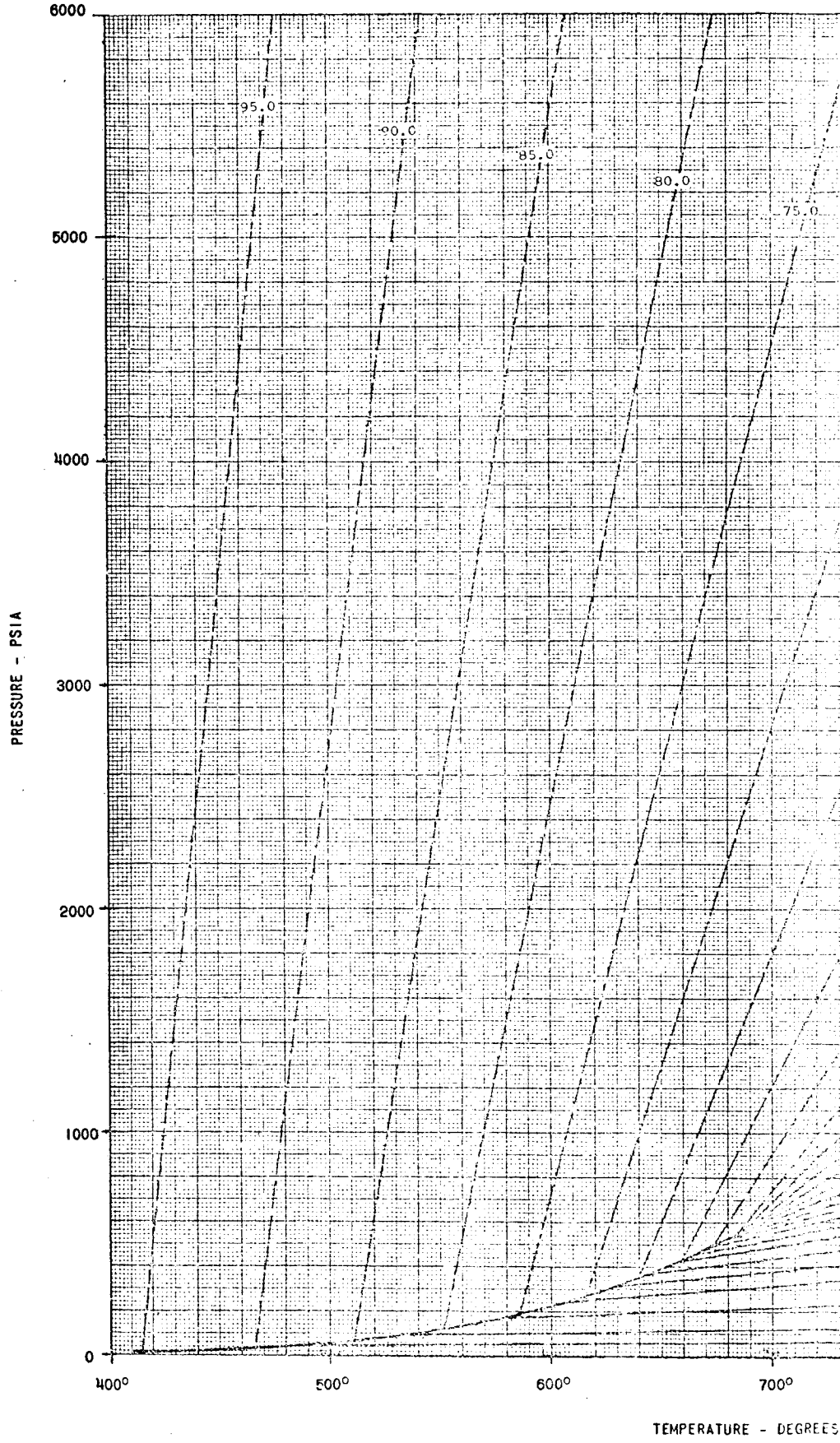


Fig. XV-18-1
VAPOR PRESSURE
OF FREON-12


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
95.0
90.0
85.0
80.0
75.0
400°
500°
600°
700°
TEMPERATURE - DEGREES

XV-18-2-1

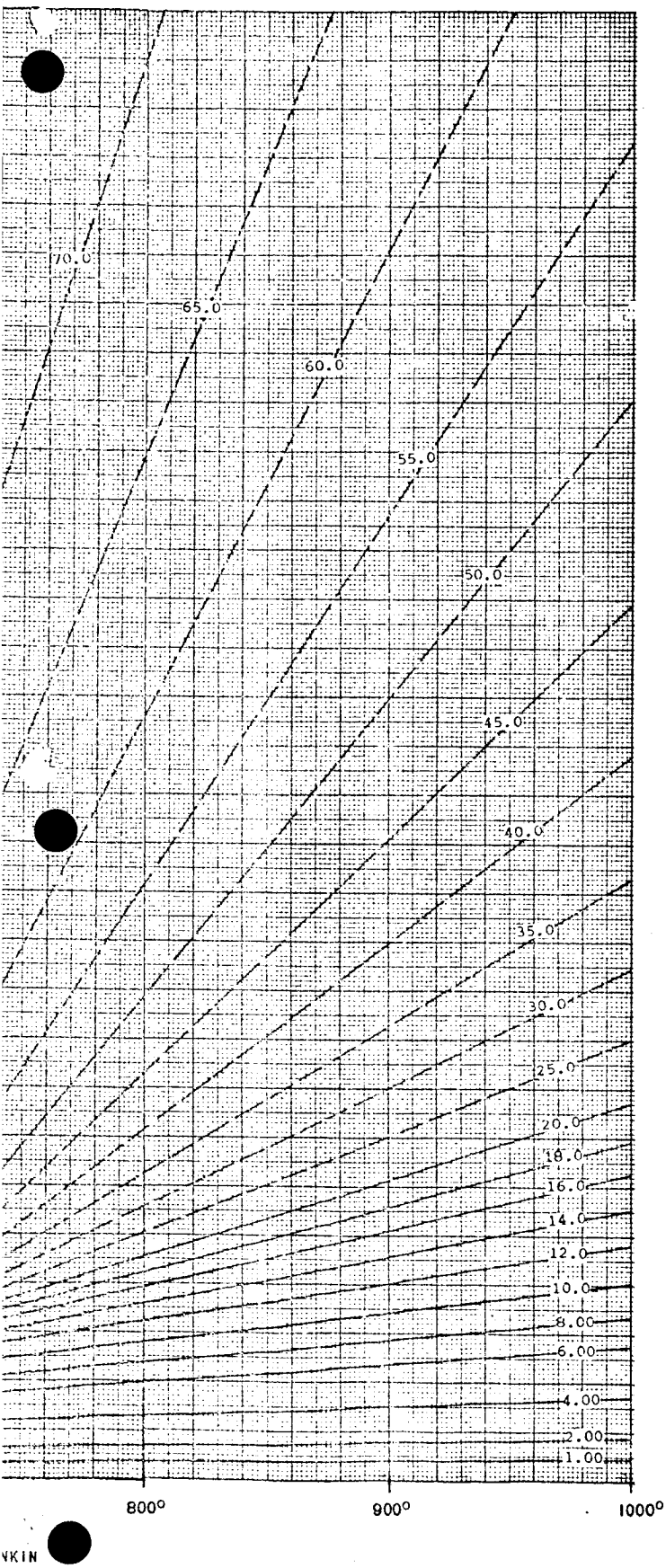


FIG. XV-18-2
FREON 12 (CCl_2F_2)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

COMMONLY ACCEPTED
DATA

EXTRAPOLATED OR
UNCONFIRMED DATA

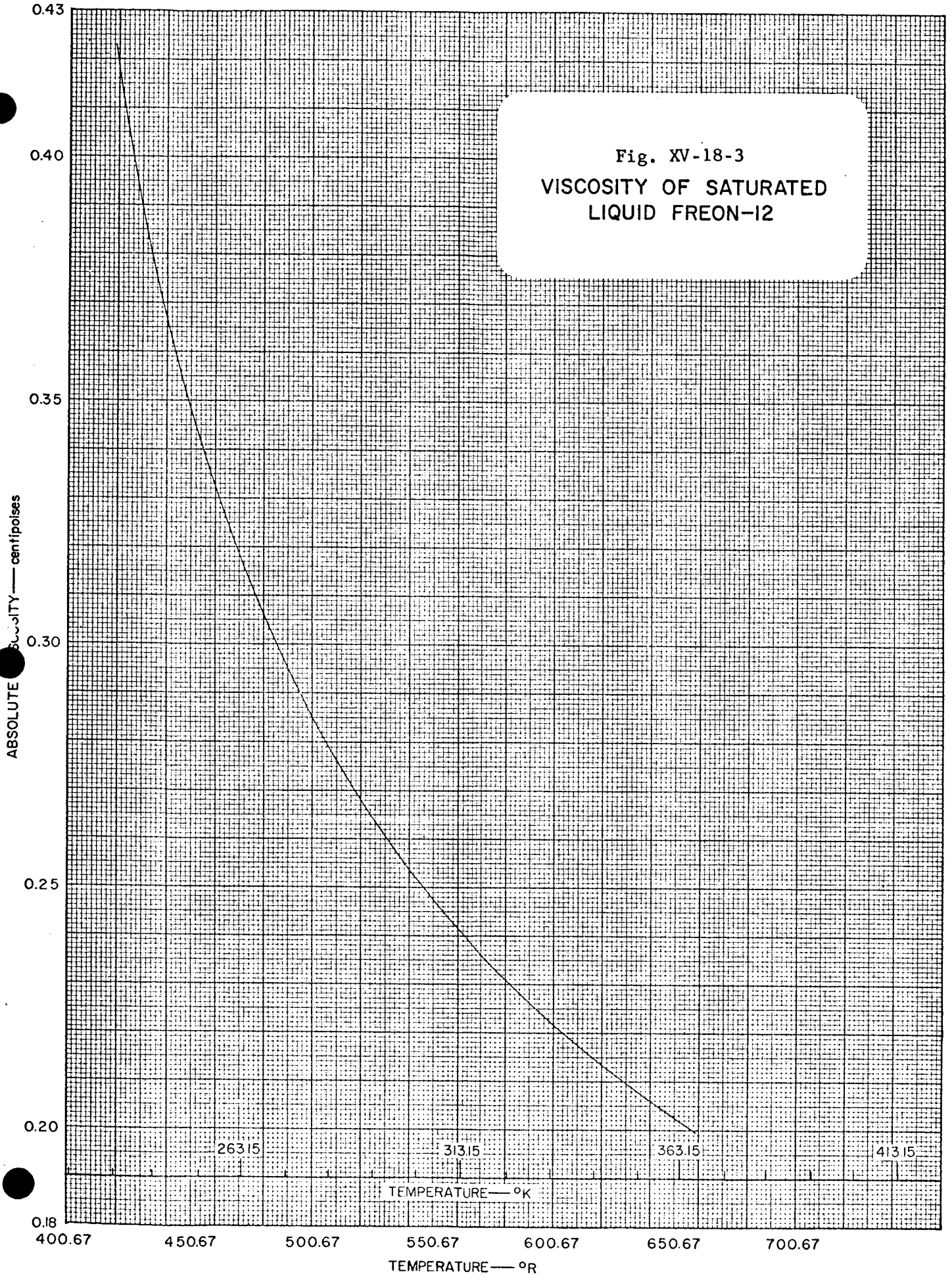


Fig. XV-18-3
VISCOSITY OF SATURATED LIQUID FREON-12

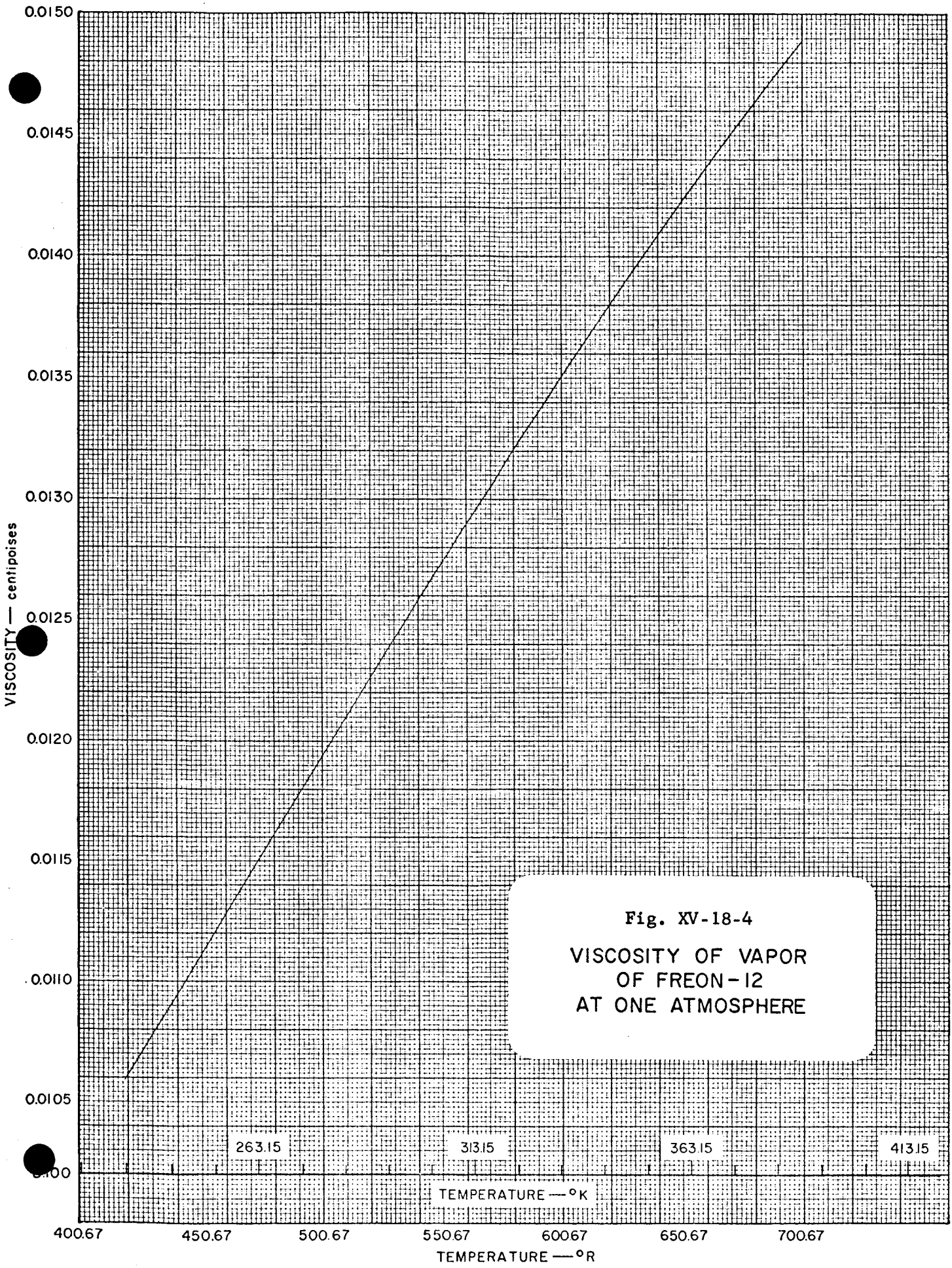


Fig. XV-18-4

VISCOSITY OF VAPOR OF FREON-12 AT ONE ATMOSPHERE

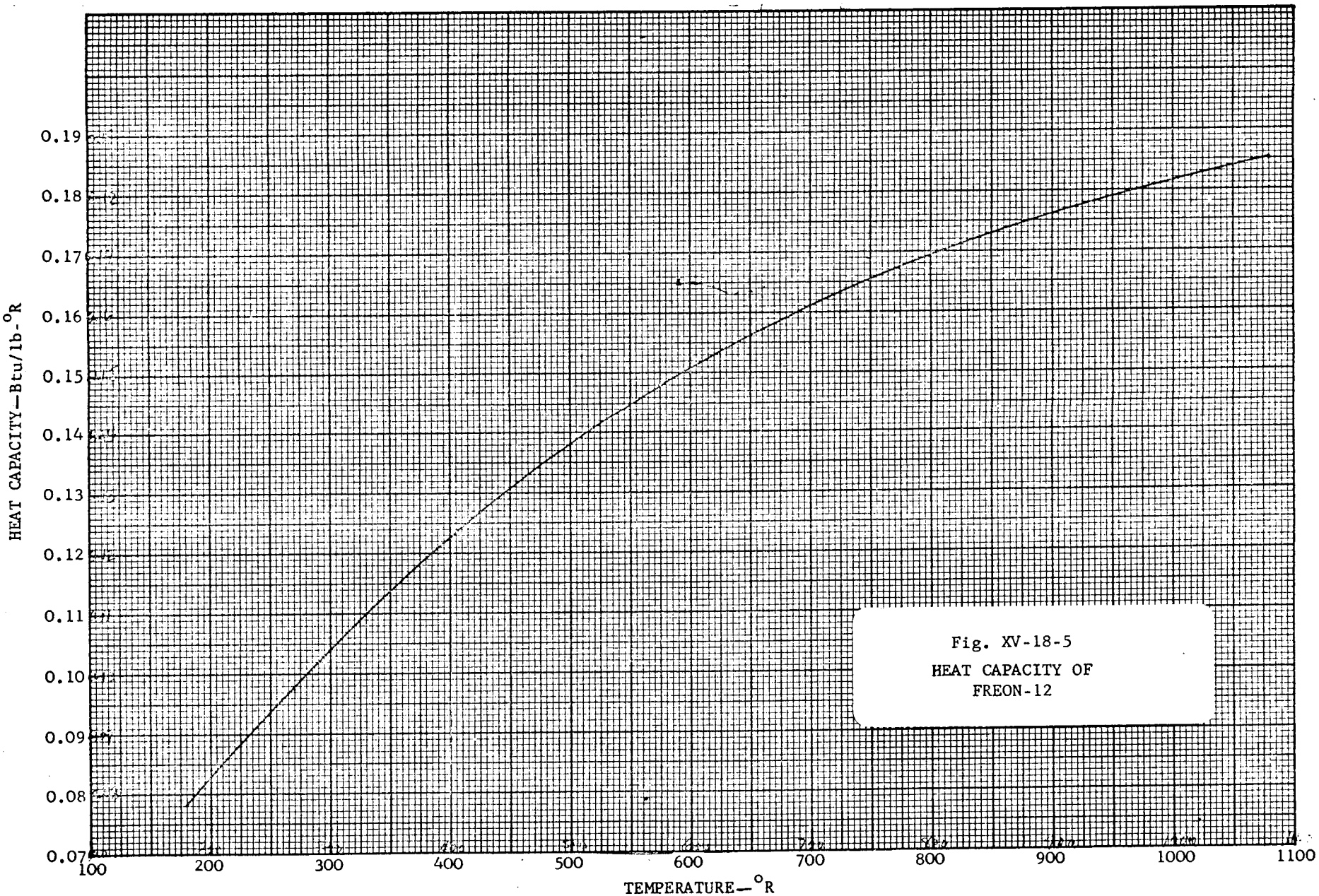


Fig. XV-18-5
HEAT CAPACITY OF
FREON-12

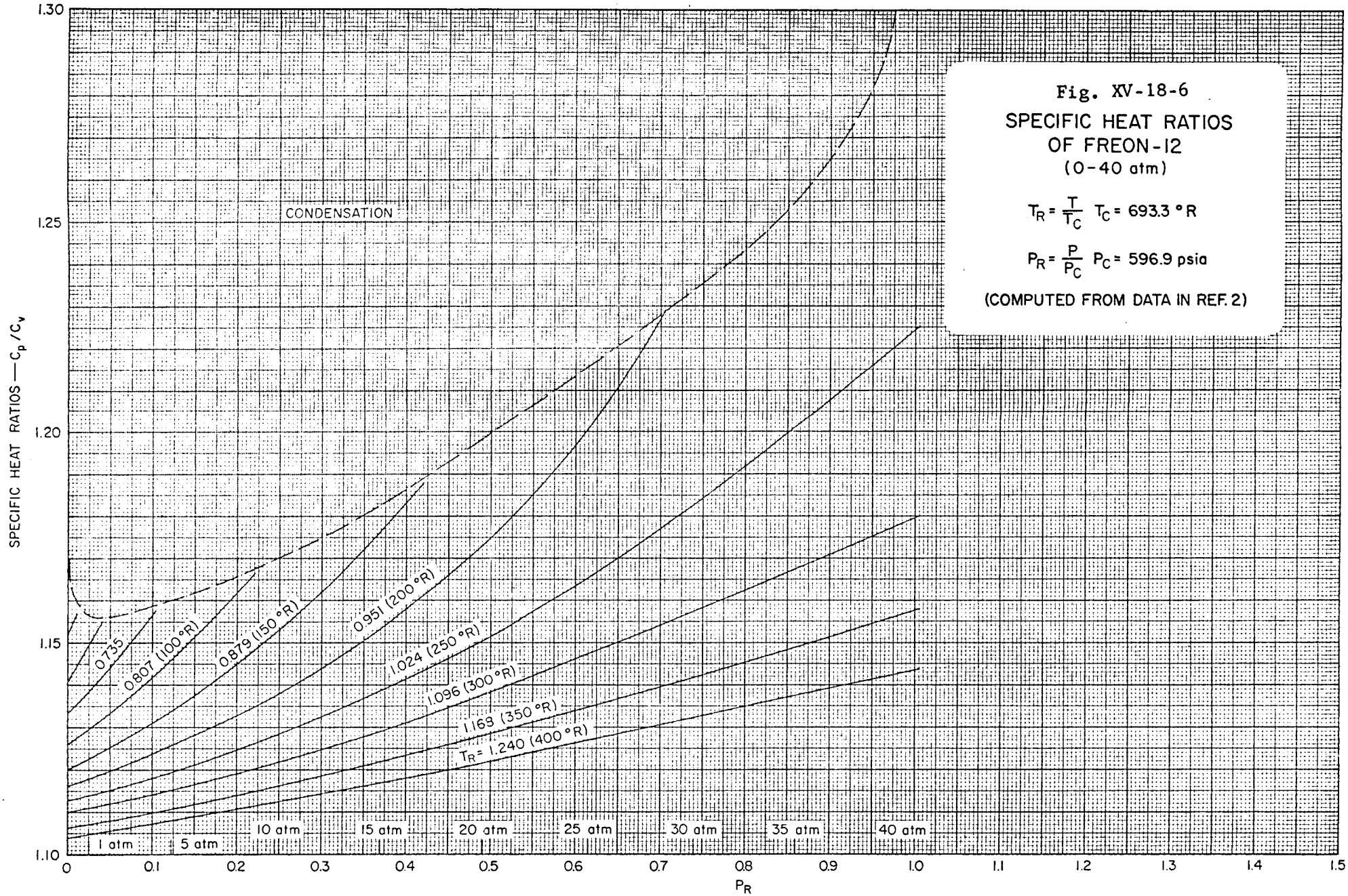


Fig. XV-18-6
SPECIFIC HEAT RATIOS
OF FREON-12
(0-40 atm)
$T_R = \frac{T}{T_C}$ T_C = 693.3 °R
$P_R = \frac{P}{P_C}$ P_C = 596.9 psia
(COMPUTED FROM DATA IN REF. 2)
CONDENSATION
0.735
0.807 (100 °R)
0.879 (150 °R)
0.951 (200 °R)
1.024 (250 °R)
1.096 (300 °R)
1.168 (350 °R)
T_R = 1.240 (400 °R)
1 atm
5 atm
10 atm
15 atm
20 atm
25 atm
30 atm
35 atm
40 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.30
1.25
1.20
1.15
1.10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5

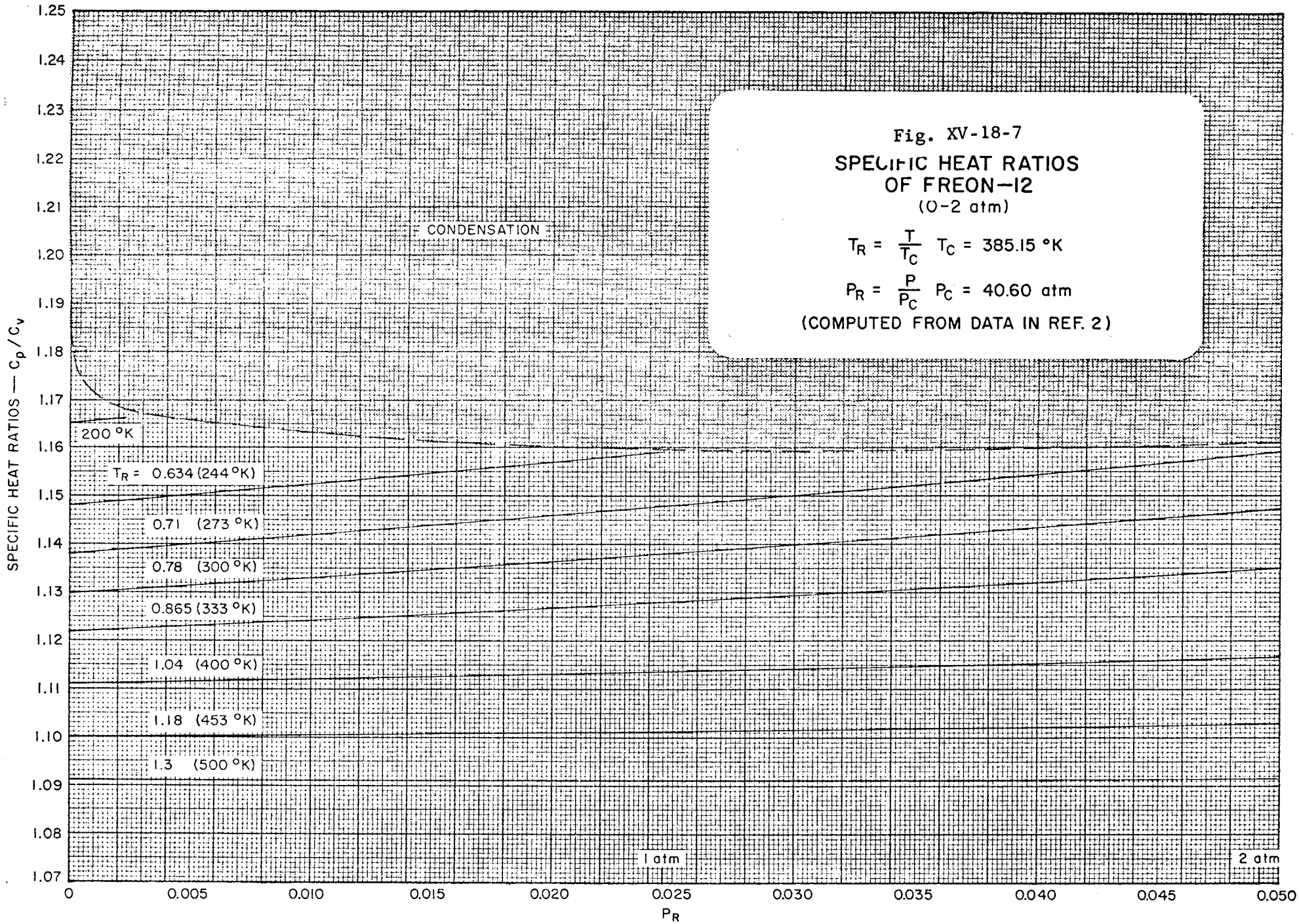


Fig. XV-18-7
SPECIFIC HEAT RATIOS
OF FREON-12
(0-2 atm)
$T_R = \frac{T}{T_C}$ T_C = 385.15 °K
$P_R = \frac{P}{P_C}$ P_C = 40.60 atm
(COMPUTED FROM DATA IN REF. 2)
CONDENSATION
200 °K
T_R = 0.634 (244 °K)
0.71 (273 °K)
0.78 (300 °K)
0.865 (333 °K)
1.04 (400 °K)
1.18 (453 °K)
1.3 (500 °K)
1 atm
2 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.25
1.24
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
1.08
1.07
0
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050

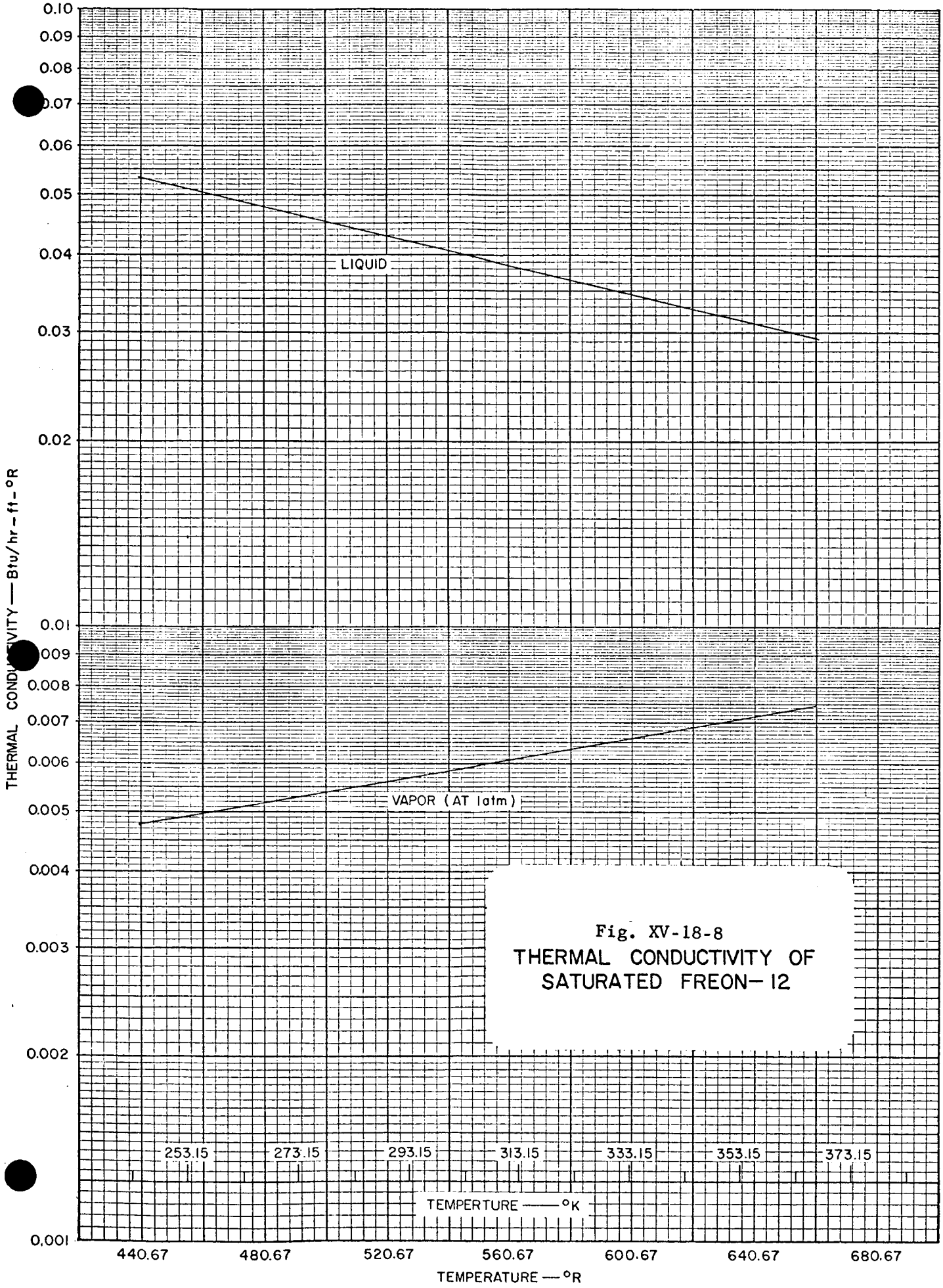


Fig. XV-18-8
THERMAL CONDUCTIVITY OF SATURATED FREON-12

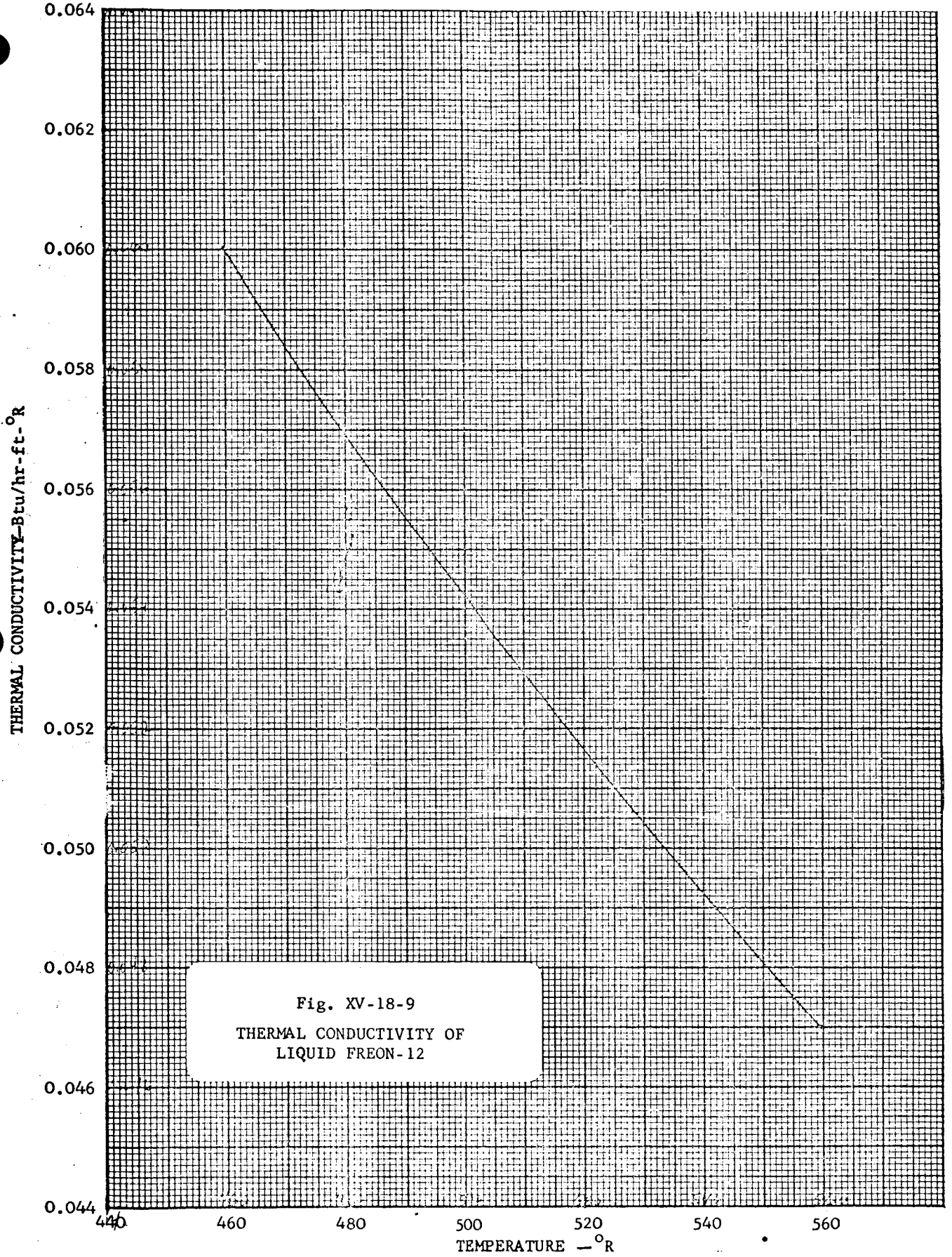


Fig. XV-18-9

THERMAL CONDUCTIVITY OF LIQUID FREON-12

XV-18 FREON-12 REFERENCES

1. Du Pont de Nemours, E.I. and Co. Tech. Bull. B-2.
2. Du Pont de Nemours, E.I. and Co. Tech. Bull. T-12.
3. Du Pont de Nemours, E.I. and Co. Bull. B-9A.
4. Du Pont de Nemours, E.I. and Co. Bull. B-10A.
5. Gelles, E. and Pitzer, K.S. J. ACS 75, p. 5259, 1953.
6. Anon. (The Matheson Co., Inc., Matheson of Canada, Ltd., Whitby, Ontario) Matheson Gas Data Book. 1961.
7. Gunther, R.C. Refrigeration, Air Conditioning and Cold Storage. p. 745, Chilton Co., Inc., Philadelphia, Penn. 1957.
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Table XV-19-1

PHYSICAL CONSTANTS

OF

FREON-13

		REF.
Molecular Weight	104.47	5
Boiling Point @ 1 atm	-114.5°F	5
Freezing Point @ 1 atm	-293.8°F	5
Specific Volume @ 70°F, 1 atm	3.5 cu ft/lb	5
Vapor Pressure @ 70°F	473.4 psia	5
Specific Gravity, (Air = 1)	3.6	6
Density		
Liquid		
Gas @ b.p.	0.4376 lb/cu-ft	5
Critical Temperature	83.84°F	5
Critical Pressure	561 psia	5
Critical Density	36.085 lb/cu ft	5
Latent Heat of Vaporization @ b.p.	63.846 Btu/lb	5
Latent Heat of Fusion		
Specific Heat of Gas		
c_p @ -22°F, 1 atm	0.138 Btu/lb-°F	5
c_v @ -22°F, 1 atm	0.1178 Btu/lb-°F	
Specific Heat Ratio, c_p/c_v @ -22°F, 1 atm	1.172	5
Thermal Conductivity @ -94°F, 1 atm	0.09 Btu/hr-ft-°F	5
Viscosity		
Liquid		
Gas @ 86°F, 1 atm	2.486×10^{-4} lb/ft-sec	5
Solubility in Water @ 77°F, 1 atm	0.009% (by wt.)	5
Surface Tension		

Table XV-19-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR FREON-13
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.785457	0.811555	596.947	11.5431
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0125817	0.0129997	9.56209	0.184901
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Density \ Pressure	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.436365	0.450864	331.637	6.41285
mole/cm^3	45.5871	47.1018	34646.2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00698983	0.00722206	5.31227	0.102722
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-19-2

VAPOR PRESSURE OF FREON-13 (Ref. 2)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
144.26	259.67	0.4329	233.15	419.67	87.43
155.37	279.67	1.238	244.26	439.67	126.4
166.48	299.67	3.104	255.37	459.67	176.8
177.59	319.67	6.455	266.48	479.67	240.4
188.70	339.67	12.48	277.59	499.67	319.60
199.82	359.67	22.23	288.71	519.67	417.0
210.93	379.67	36.98	299.82	539.67	535.5
222.04	399.67	58.19			

(See Figure XV-19-1)

Table XV-19-3

DENSITY OF FREON-13 (Ref. 2)

DENSITY lb/ft^3									
PRESSURE psia / TEMP. °R	100	200	400	600	1000	1400	2000	4000	6000
380	(90.3)	(90.5)	(90.8)	(91.2)	(91.9)	(92.7)	(93.6)	-	-
420	(83.9)	(84.1)	(84.7)	(85.3)	(86.3)	(87.3)	(88.6)	(92.1)	(95.0)
460	2.39	(75.7)	(77.7)	(78.6)	(80.2)	(81.5)	(83.1)	(87.5)	(90.8)
500	2.13	4.77	(68.0)	(70.0)	(72.7)	(75.0)	(77.4)	(83.0)	(86.8)
540	1.93	4.17	10.58	(55.0)	(62.9)	(66.9)	(70.8)	(78.4)	(83.0)
580	1.77	3.74	8.66	(16.4)	(48.0)	(57.4)	(63.6)	(73.4)	(78.9)
620	1.64	3.42	7.57	(13.1)	(30.0)	(46.8)	(56.3)	(68.5)	(75.0)
660	1.52	3.15	6.80	(11.2)	(22.2)	(35.6)	(48.9)	(63.9)	(71.0)
700	1.43	2.93	6.21	(10.0)	(18.6)	(28.6)	(42.0)	(59.8)	(67.4)
740	1.34	2.75	5.74	(9.0)	(16.0)	(24.0)	(36.0)	(56.1)	(64.0)
780	1.27	2.58	5.18	(8.3)	(14.4)	(21.1)	(31.4)	(52.5)	(59.8)

(See Figure XV-19-2)

NOTE: ( ) Data Extrapolated.

Table XV-19-4

VISCOSITY OF FREON-13 (Ref. 4)

TEMPERATURE		ABSOULTE VISCOSITY
°K	°R	micro-poises
100	180	50.6
200	360	101.9
300	540	150.2
400	720	193.1
500	900	231.5
600	1080	266.6

(See Figure XV-19-3)

Table XV-19-5

HEAT CAPACITY OF FREON-13 (Ref. 3)

TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R
100	180	0.0839
150	270	0.1017
200	360	0.1210
250	450	0.1383
298.16	536.7	0.1529
300	540	0.1553
400	720	0.1774
500	900	0.1945
600	1080	0.2068

(See Figure XV-19-4)

Table XV-19-6

THERMAL CONDUCTIVITY OF GASEOUS FREON-13 (Ref. 4)

TEMPERATURE		THERMAL CONDUCTIVITY
°K	°R	Btu/hr-ft °R
100	180	0.00148
200	360	0.00416
300	540	0.00767
400	720	0.0113
500	900	0.0149
600	1080	0.0182

(See Figure XV-19-7)

Table XV-19-7

SELECTED VALUES OF SATURATION PROPERTIES OF FREON-13 (Ref. 2)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-$^\circ$R	
$^\circ$R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
259.69	0.4329	0.00947	61.33	105.6	0.0163	-34.551	73.096	38.545	-0.10081	0.18066
269.69	0.7490	0.00957	36.74	104.4	0.0272	-32.429	72.029	39.600	-0.09313	0.17395
279.69	1.238	0.00969	22.99	103.2	0.0435	-30.298	70.970	40.672	-0.08575	0.16800
289.69	1.967	0.00980	14.942	102.0	0.0669	-28.208	69.904	41.696	-0.07858	0.16273
299.69	3.104	0.00992	9.750	100.8	0.1026	-26.083	68.808	42.725	-0.07213	0.15747
309.69	4.464	0.01004	6.976	99.60	0.1434	-24.010	67.783	43.773	-0.06491	0.15396
319.69	6.455	0.01017	4.950	98.33	0.2020	-21.902	66.696	44.794	-0.05844	0.15019
329.69	9.080	0.01031	3.605	96.99	0.2774	-19.792	65.596	45.804	-0.05209	0.14687
339.69	12.48	0.01045	2.681	95.69	0.3730	-17.671	64.473	46.802	-0.04590	0.14390
349.69	16.81	0.01060	2.031	94.34	0.4924	-15.527	63.316	47.789	-0.03977	0.14129
359.69	22.23	0.01075	1.5642	93.02	0.6393	-13.387	62.138	48.751	-0.03286	0.13889
369.69	28.89	0.01091	1.2232	91.66	0.8175	-11.241	60.941	49.700	-0.02806	0.13678
379.69	36.98	0.01109	0.9689	90.17	1.032	- 9.052	59.672	50.620	-0.02230	0.13486
389.69	46.68	0.01127	0.7766	88.73	1.288	- 6.843	58.362	51.519	-0.01665	0.13312
399.69	58.19	0.01146	0.6289	87.26	1.590	- 4.604	56.993	52.389	-0.01106	0.13153
409.69	71.71	0.01167	0.5139	85.69	1.946	- 2.320	55.546	53.226	-0.00548	0.13009
419.69	87.43	0.01189	0.4234	84.10	2.362	0.000	54.023	54.023	0.00000	0.12872
429.69	105.6	0.01213	0.3512	82.44	2.847	2.363	52.416	54.779	0.00545	0.12744
439.69	126.4	0.01239	0.2930	80.71	3.413	4.809	50.668	55.477	0.01096	0.12620
449.69	150.1	0.01268	0.2454	78.86	4.075	7.484	48.630	56.114	0.01686	0.12500
459.69	176.8	0.01299	0.2066	76.98	4.840	10.052	46.638	56.690	0.02234	0.12380

Table XV-19-7 (contd)

SELECTED VALUES OF SATURATION PROPERTIES OF FREON-13 (Ref. 2)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-^oR	
^oR	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
469.69	206.8	0.01335	0.17443	74.91	5.733	12.696	44.479	57.175	0.02789	0.12259
479.69	240.4	0.01375	0.14732	72.73	6.788	15.443	42.100	57.543	0.03351	0.12128
489.69	277.9	0.01422	0.12437	70.32	8.040	18.247	39.472	57.719	0.03921	0.11982
499.69	319.6	0.01477	0.10455	67.70	9.565	21.370	36.450	57.820	0.04516	0.11811
504.69	342.2	0.01509	0.09565	66.27	10.45	22.979	34.769	57.748	0.04826	0.11715
509.69	365.9	0.01546	0.08734	64.68	11.45	24.651	32.958	57.609	0.05143	0.11609
514.69	390.8	0.01588	0.07945	62.97	12.59	26.418	30.946	57.364	0.05473	0.11486
519.69	417.0	0.01637	0.07189	61.09	13.91	28.310	28.677	56.987	0.05824	0.11342
524.69	444.5	0.01696	0.06468	58.96	15.46	30.322	26.137	56.459	0.06193	0.11174
529.69	473.4	0.01771	0.05767	56.46	17.34	32.515	23.193	55.708	0.06591	0.10970
534.69	503.7	0.01874	0.05027	53.36	19.89	35.110	19.382	54.492	0.07059	0.10684
539.69	535.5	0.02047	0.04131	48.85	24.20	38.527	13.565	52.092	0.07672	0.10185
543.62 (Critical)	561.3	0.02772	0.02772	36.08	36.08	45.271		45.271	0.08898	0.08898

V = volume in cu-ft/lb
H = enthalpy in btu/lb
S = entropy in btu/lb-°R
(saturation properties in parentheses)

Table XV-19-8.1

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 1, 2, 4 psia (Ref. 2)

TEMPERATURE	1 psia (sat'n temp. 275.32°R)			2 psia (sat'n temp. 290.07°R)			4 psia (sat'n temp. 306.78°R)		
°R	V	H	S	V	H	S	V	H	S
(sat'n temp.)	(28.05)	(40.23)	(0.1705)	(14.70)	(41.80)	(0.1625)			
279.69	28.51	40.70	0.1722	...	...	...	(7.722)	(43.50)	(0.1550)
299.69	30.61	43.02	0.1797	15.22	42.88	0.1662	...	...	...
319.69	32.71	45.38	0.1870	16.29	45.28	0.1736	8.077	45.07	0.1599
339.69	34.78	47.80	0.1940	17.33	47.70	0.1807	8.612	47.54	0.1673
359.69	36.85	50.26	0.2011	18.38	50.19	0.1876	9.149	50.05	0.1742
379.69	38.93	52.78	0.2078	19.42	52.72	0.1944	9.671	52.61	0.1810
399.69	40.98	55.36	0.2143	20.46	55.31	0.2010	10.19	55.22	0.1877
419.69	43.05	58.00	0.2207	21.49	57.96	0.2076	10.72	57.88	0.1942
439.69	45.11	60.71	0.2270	22.53	60.67	0.2139	11.23	60.60	0.2005
459.69	47.16	63.48	0.2331	23.56	63.45	0.2200	11.75	63.39	0.2066
479.69	49.23	66.33	0.2392	24.58	66.30	0.2261	12.27	66.24	0.2128
499.69	51.28	69.24	0.2449	25.61	69.21	0.2320	12.78	69.16	0.2187
519.69	53.35	72.22	0.2510	26.65	72.19	0.2379	13.29	72.15	0.2245
539.69	55.40	75.26	0.2569	27.68	75.24	0.2436	13.81	75.20	0.2303
559.69	57.46	78.36	0.2624	28.71	78.34	0.2492	14.34	78.31	0.2361
579.69	59.50	81.53	0.2680	29.74	81.51	0.2548	14.85	81.48	0.2416
599.69	61.56	84.76	0.2734	30.77	84.74	0.2602	15.37	84.71	0.2470
619.69	63.62	88.04	0.2788	31.79	88.02	0.2657	15.88	87.99	0.2525
639.69	65.67	91.37	0.2843	32.82	91.36	0.2711	16.41	91.33	0.2578
659.69	67.73	94.78	0.2895	33.86	94.76	0.2763	16.92	94.73	0.2630

Table XV-19-8.1 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 1, 2, 4 psia

TEMPERATURE	1 psia (sat'n temp. 275.32°R)			2 psia (sat'n temp. 290.07°R)			4 psia (sat'n temp. 306.78°R)		
°R	V	H	S	V	H	S	V	H	S
679.69	69.78	98.21	0.2946	34.89	98.20	0.2813	17.43	98.17	0.2682
699.69	71.84	101.70	0.2996	35.91	101.69	0.2862	17.95	101.67	0.2732
719.69	73.89	105.24	0.3045	36.94	105.23	0.2911	18.46	105.21	0.2782
739.69	75.94	108.83	0.3092	37.97	108.82	0.2961	18.97	108.80	0.2830
759.69	78.01	112.47	0.3140	38.99	112.46	0.3011	19.49	112.44	0.2879
779.69	80.06	116.13	0.3187	40.02	116.13	0.3058	20.00	116.11	0.2927
799.69	82.12	119.85	0.3231	41.05	119.84	0.3105	20.51	119.83	0.2974
819.69	84.17	123.60	0.3275	42.08	123.59	0.3153	21.03	123.58	0.3022
839.69	86.22	127.40	0.3319	43.10	127.39	0.3197	21.55	127.37	0.3066
859.69	88.28	131.22	0.3362	44.14	131.21	0.3244	22.06	131.20	0.3111
879.69	90.33	135.08	0.3404	45.17	135.07	0.3286	22.58	135.06	0.3156
899.69	92.39	138.96	0.3445	46.19	138.95	0.3331	23.09	138.94	0.3200
919.69	94.42	142.89	0.3486	47.22	142.88	0.3374	23.61	142.87	0.3242
939.69	96.50	146.83	0.3526	48.25	146.83	0.3416	24.12	146.82	0.3285
959.69	98.56	150.80	0.3566	49.27	150.80	0.3459	24.63	150.79	0.3327

Table XV-19-8.2

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 8, 10, 20 psia (Ref. 2)

TEMPERATURE	8 psia (sat'n temp. 325.89°R)			10 psia (sat'n temp. 332.65°R)			20.psia (sat'n temp. 355.84°R)		
°R	V	H	S	V	H	S	V	H	S
(sat'n temp.)	(4.055)	(45.47)	(0.1481)	(3.296)	(46.12)	(0.1459)			
319.69	...	...	...	...	...	...			
339.69	4.251	47.20	0.1533	3.376	47.02	0.1486	(1.724)	(48.32)	(0.1397)
359.69	4.528	49.78	0.1605	3.602	49.64	0.1560	1.749	48.91	0.1413
379.69	4.795	52.38	0.1674	3.819	52.27	0.1628	1.866	51.69	0.1487
399.69	5.062	55.03	0.1742	4.034	54.93	0.1694	1.981	54.40	0.1557
419.69	5.325	57.72	0.1807	4.248	57.64	0.1763	2.092	57.22	0.1624
439.69	5.589	60.46	0.1871	4.460	60.39	0.1827	2.202	60.03	0.1691
459.69	5.851	63.27	0.1933	4.670	63.20	0.1889	2.311	62.89	0.1754
479.69	6.115	66.13	0.1994	4.883	66.08	0.1951	2.418	65.80	0.1816
499.69	6.375	69.07	0.2055	5.092	69.02	0.2010	2.525	68.77	0.1875
519.69	6.635	72.06	0.2113	5.301	72.01	0.2069	2.631	71.79	0.1934
539.69	6.895	75.12	0.2170	5.511	75.07	0.2127	2.738	74.87	0.1993
559.69	7.155	78.23	0.2226	5.719	78.19	0.2184	2.842	78.00	0.2050
579.69	7.414	81.40	0.2283	5.925	81.37	0.2241	2.948	81.20	0.2106
599.69	7.674	84.64	0.2337	6.133	84.61	0.2295	3.054	84.45	0.2162
619.69	7.933	87.93	0.2390	6.341	87.90	0.2348	3.157	87.75	0.2216
639.69	8.192	91.28	0.2445	6.548	91.25	0.2401	3.263	91.11	0.2270
659.69	8.450	94.67	0.2497	6.755	94.64	0.2453	3.367	94.51	0.2322

Table XV-19-8.2 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 at 8, 10, 20 psia

TEMPERATURE	8 psia (sat'n temp. 325.89°R)			10 psia (sat'n temp. 332.65°R)			20 psia (sat'n temp. 355.84°R)		
°R	V	H	S	V	H	S	V	H	S
679.69	8.707	98.12	0.2548	6.961	98.10	0.2505	3.471	97.97	0.2373
699.69	8.965	101.62	0.2599	7.168	101.60	0.2557	3.574	101.48	0.2424
719.69	9.222	105.16	0.2649	7.374	105.14	0.2608	3.678	105.03	0.2473
739.69	9.480	108.76	0.2698	7.580	108.74	0.2656	3.782	108.63	0.2524
759.69	9.736	112.39	0.2747	7.787	112.37	0.2705	3.885	112.27	0.2572
779.69	9.995	116.07	0.2794	7.993	116.05	0.2752	3.989	115.95	0.2620
799.69	10.25	119.79	0.2842	8.200	119.77	0.2799	4.093	119.67	0.2667
819.69	10.51	123.54	0.2889	8.406	123.53	0.2846	4.197	123.44	0.2713
839.69	10.77	127.34	0.2934	8.612	127.32	0.2891	4.301	127.24	0.2758
859.69	11.03	131.16	0.2979	8.819	131.15	0.2937	4.405	131.06	0.2804
879.69	11.28	135.02	0.3023	9.025	135.01	0.2981	4.509	134.93	0.2848
899.69	11.54	138.92	0.3067	9.232	138.90	0.3025	4.612	138.82	0.2892
919.69	11.80	142.84	0.3110	9.438	142.82	0.3068	4.716	142.75	0.2936
939.69	12.05	146.79	0.3153	9.645	146.77	0.3111	4.820	146.70	0.2979
959.69	12.31	150.76	0.3195	9.851	150.74	0.3152	4.922	150.68	0.3020

Table XV-19-8.3

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 40, 80, 100 psia (Ref. 2)

TEMPERATURE	40 psia (sat'n temp. 383.00°R)			80 psia (sat'n temp. 415.15°R)			100 psia (sat'n temp. 426.75°R)		
°R	V	H	S	V	H	S	V	H	S
(sat'n temp.)	(0.8994)	(50.90)	(0.1343)	(0.4619)	(53.70)	(0.1293)			
379.69	...	...	...	...	...	...	(0.3707)	(54.61)	(0.1279)
399.69	0.9526	53.37	0.1406	...	...	...	...	...	...
419.69	1.014	56.37	0.1477	0.4705	54.45	0.1311	0.3900	56.82	0.1330
439.69	1.072	59.27	0.1545	0.5052	57.71	0.1387	0.4180	60.11	0.1403
459.69	1.130	62.25	0.1612	0.5371	60.88	0.1458	0.4451	63.44	0.1473
479.69	1.186	65.22	0.1675	0.5694	64.01	0.1525	0.4704	66.60	0.1540
499.69	1.242	68.26	0.1736	0.5993	67.18	0.1589	0.4951	69.88	0.1603
519.69	1.296	71.33	0.1797	0.6292	70.36	0.1653	0.5191	73.11	0.1664
539.69	1.351	74.45	0.1856	0.6581	73.58	0.1713	0.5425	76.41	0.1724
559.69	1.406	77.61	0.1914	0.6864	76.83	0.1772	0.5663	79.75	0.1783
579.69	1.459	80.84	0.1970	0.7157	80.11	0.1830	0.5892	83.09	0.1840
599.69	1.513	84.12	0.2026	0.7433	83.45	0.1886	0.6112	86.50	0.1895
619.69	1.566	87.44	0.2080	0.7703	86.80	0.1941	0.6335	89.94	0.1950
639.69	1.620	90.80	0.2134	0.7976	90.23	0.1996	0.6559	93.41	0.2003
659.69	1.672	94.24	0.2187	0.8252	93.69	0.2048			

Table XV-19-8.3 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 at 40, 80, 100 psia

TEMPERATURE	40 psia (sat'n temp. 383.00°R)			80 psia (sat'n temp. 415.15°R)			100 psia (sat'n temp. 426.75°R)		
°R	V	H	S	V	H	S	V	H	S
679.69	1.725	97.71	0.2239	0.8527	97.20	0.2101	0.6781	96.94	0.2055
699.69	1.778	101.23	0.2291	0.8801	100.76	0.2153	0.7003	100.49	0.2108
719.69	1.830	104.80	0.2341	0.9070	104.29	0.2203	0.7221	104.10	0.2158
739.69	1.883	108.41	0.2390	0.9339	107.97	0.2253	0.7440	107.75	0.2209
759.69	1.936	112.06	0.2438	0.9608	111.65	0.2301	0.7658	111.44	0.2258
779.69	1.988	115.75	0.2486	0.9873	115.36	0.2350	0.7872	115.15	0.2306
799.69	2.040	119.49	0.2533	1.014	119.11	0.2398	0.8087	118.92	0.2353
819.69	2.093	123.25	0.2580	1.040	122.89	0.2445	0.8301	122.72	0.2401
839.69	2.145	127.07	0.2626	1.067	126.71	0.2491	0.8516	126.54	0.2446
859.69	2.197	130.90	0.2671	1.094	130.57	0.2536	0.8732	130.40	0.2492
879.69	2.250	134.77	0.2716	1.120	134.46	0.2581	0.8946	134.29	0.2537
899.69	2.301	138.67	0.2760	1.146	138.37	0.2625	0.9160	138.22	0.2581
919.69	2.354	142.61	0.2803	1.173	142.32	0.2668	0.9371	142.17	0.2624
939.69	2.405	146.56	0.2845	1.199	146.28	0.2710	0.9585	146.14	0.2668
959.69	2.457	150.55	0.2887	1.226	150.28	0.2753	0.9798	150.14	0.2709

Table XV-19-8.4

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 200, 300, 400 psia (Ref. 2)

TEMPERATURE	200 psia (sat'n temp. 467.51°R)			300 psia (sat'n temp. 495.10°R)			400 psia (sat'n temp. 516.48°R)		
°R	V	H	S	V	H	S	V	H	S
(sat'n temp.)	(0.1809)	(57.10)	(0.1227)						
419.69	...	...	....						
439.69	...	...	...						
459.69	...	...	...	(0.1133)	(57.86)	(0.1189)	(0.0767)	(57.15)	(0.1145)
479.69	0.1929	59.60	0.1280	...	...	...	...	...	...
499.69	0.2098	63.41	0.1358	0.1175	59.04	0.1213	...	...	...
519.69	0.2254	67.03	0.1431	0.1322	63.66	0.1304	0.07974	58.24	0.1166
539.69	0.2399	70.67	0.1499	0.1447	67.77	0.1382	0.09448	63.82	0.1272
559.69	0.2537	74.21	0.1564	0.1562	71.64	0.1453	0.1056	68.69	0.1358
579.69	0.2671	77.75	0.1626	0.1664	75.45	0.1520	0.1155	72.80	0.1432
599.69	0.2801	81.24	0.1686	0.1764	79.28	0.1584	0.1241	77.13	0.1501
619.69	0.2924	84.83	0.1744	0.1860	83.05	0.1645	0.1321	81.07	0.1567
639.69	0.3048	88.40	0.1800	0.1950	86.75	0.1704	0.1398	84.90	0.1629
659.69	0.3172	91.94	0.1856	0.2040	90.46	0.1761	0.1471	88.85	0.1689

Table XV-19-8.4 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-13 AT 200, 300, 400 psia

TEMPERATURE	200 psia (sat'n temp. 467.51°R)			300 psia (sat'n temp. 495.10°R)			400 psia (sat'n temp. 516.48°R)		
°R	V	H	S	V	H	S	V	H	S
679.69	0.3291	95.57	0.1910	0.2125	94.05	0.1817	0.1541	92.73	0.1747
699.69	0.3408	99.26	0.1964	0.2210	97.90	0.1871	0.1611	96.51	0.1803
719.69	0.3523	102.93	0.2015	0.2293	101.77	0.1925	0.1677	100.29	0.1857
739.69	0.3639	106.60	0.2065	0.2373	105.44	0.1976	0.1742	104.26	0.1910
759.69	0.3754	110.35	0.2115	0.2455	109.27	0.2027	0.1806	108.18	0.1962
779.69	0.3869	114.14	0.2164	0.2535	113.16	0.2077	0.1860	112.09	0.2013
799.69	0.3982	117.97	0.2213	0.2614	116.98	0.2126	0.1930	115.94	0.2062
819.69	0.4095	121.82	0.2261	0.2692	120.86	0.2174	0.1992	119.98	0.2110
839.69	0.4207	125.66	0.2307	0.2771	124.78	0.2221	0.2053	123.88	0.2158
859.69	0.4318	129.56	0.2353	0.2847	128.71	0.2268	0.2112	127.90	0.2205
879.69	0.4429	133.48	0.2399	0.2924	132.69	0.2314	0.2172	131.87	0.2252
899.69	0.4538	137.43	0.2443	0.2999	136.68	0.2359	0.2232	135.95	0.2297
919.69	0.4648	141.43	0.2487	0.3075	140.69	0.2403	0.2290	140.01	0.2341
939.69	0.4759	145.44	0.2530	0.3151	144.74	0.2447	0.2347	144.02	0.2385
959.69	0.4869	149.45	0.2572	0.3227	148.79	0.2489	0.2405	148.11	0.2428

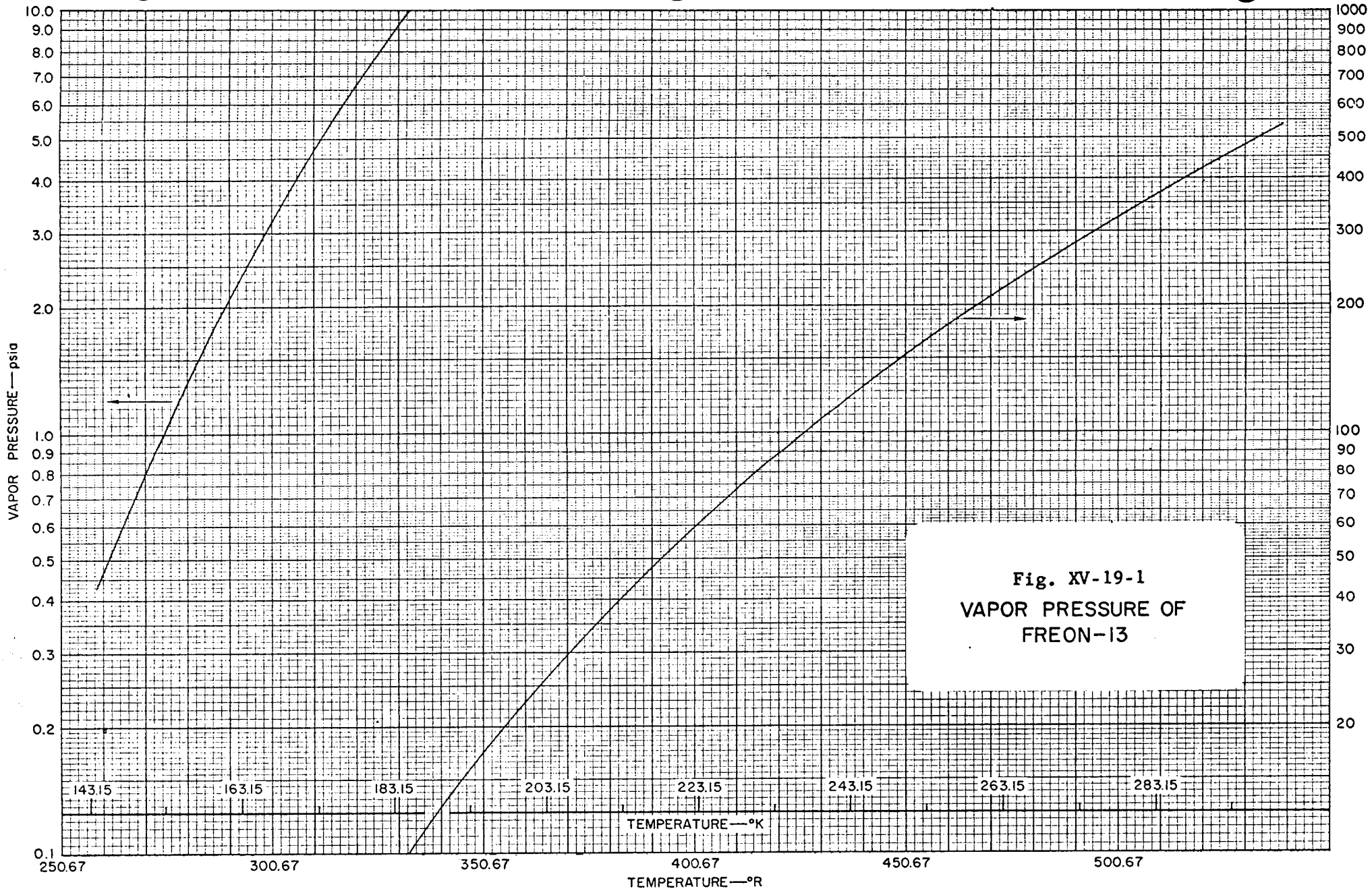
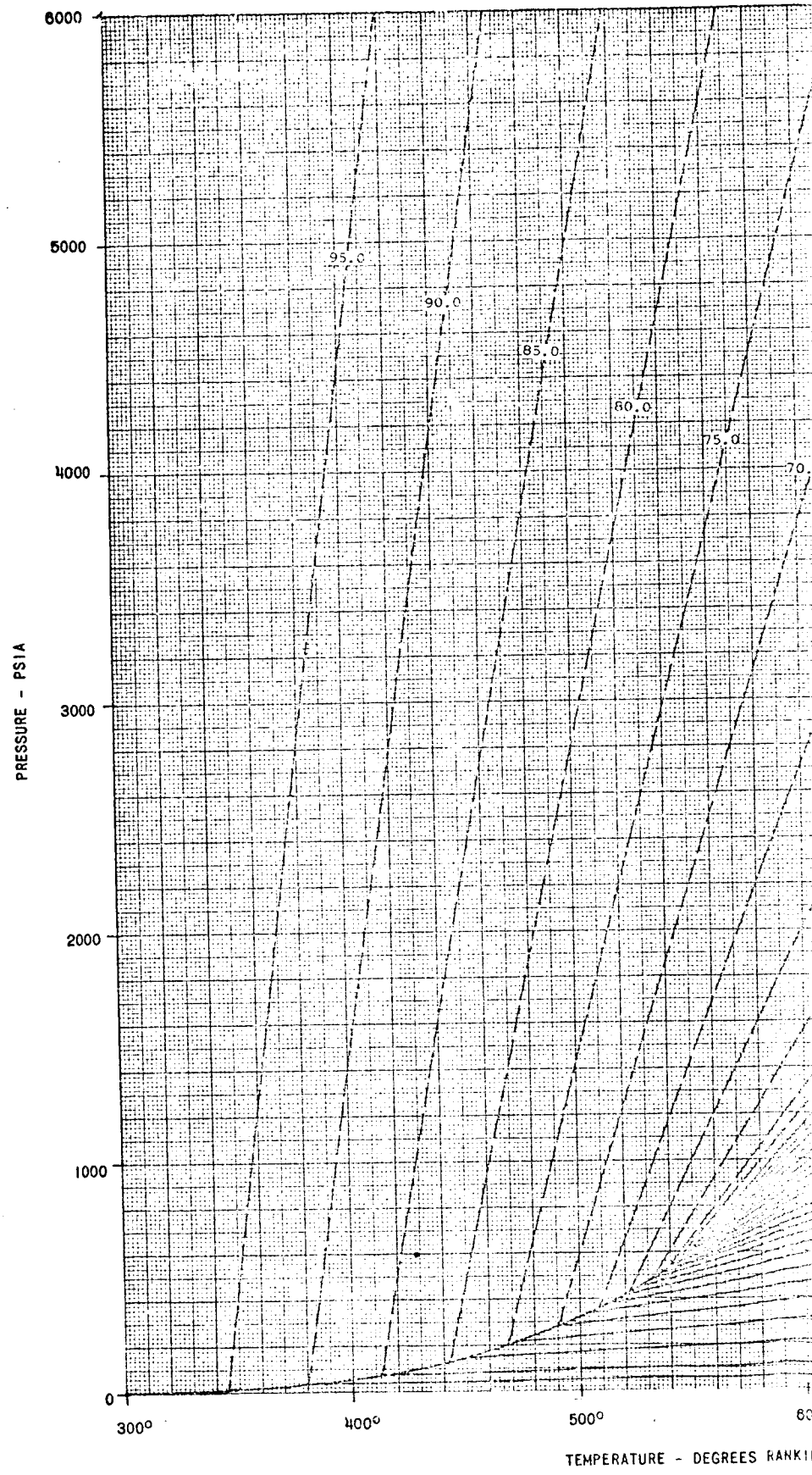


Fig. XV-19-1
VAPOR PRESSURE OF
FREON-13


6000
5000
4000
3000
2000
1000
0
PRESSURE - PSIA
95.0
90.0
85.0
80.0
75.0
70.
300°
400°
500°
TEMPERATURE - DEGREES RANKI

XU-19-2-1

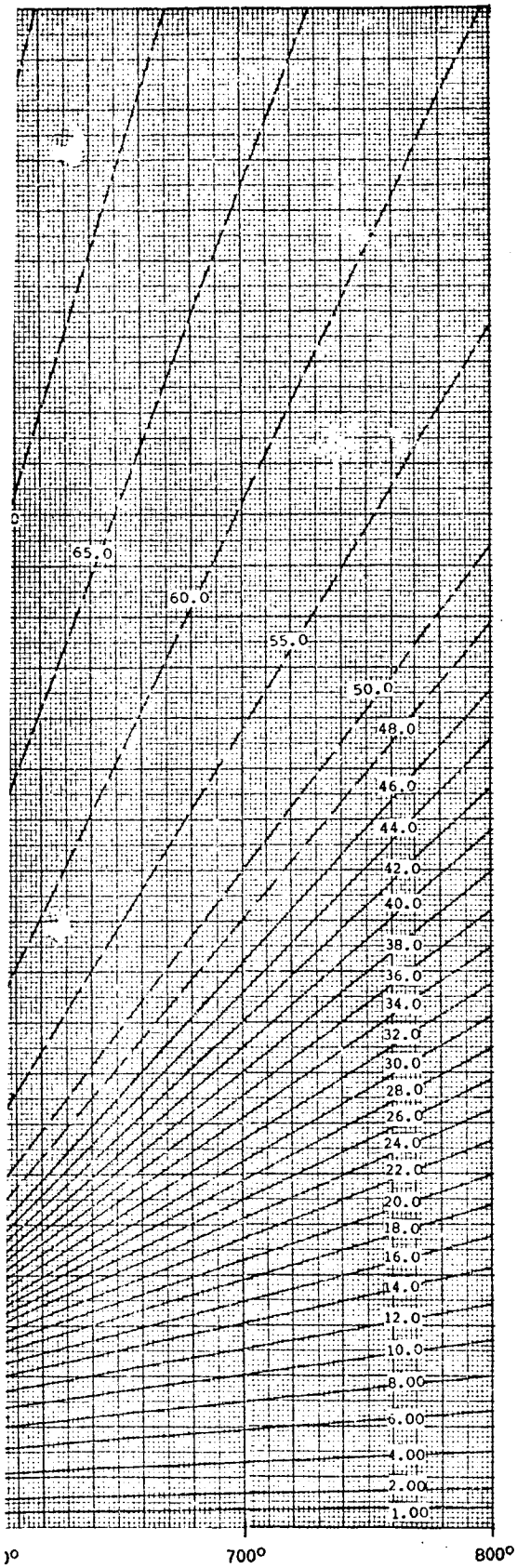


FIG. XV-19-2
FREON 13 (CCl_3F)

CONSTANT DENSITY (lb/cu-ft)
AS A FUNCTION OF
PRESSURE VERSUS TEMPERATURE

——— COMMONLY ACCEPTED DATA

— — — EXTRAPOLATED OR UNCONFIRMED DATA

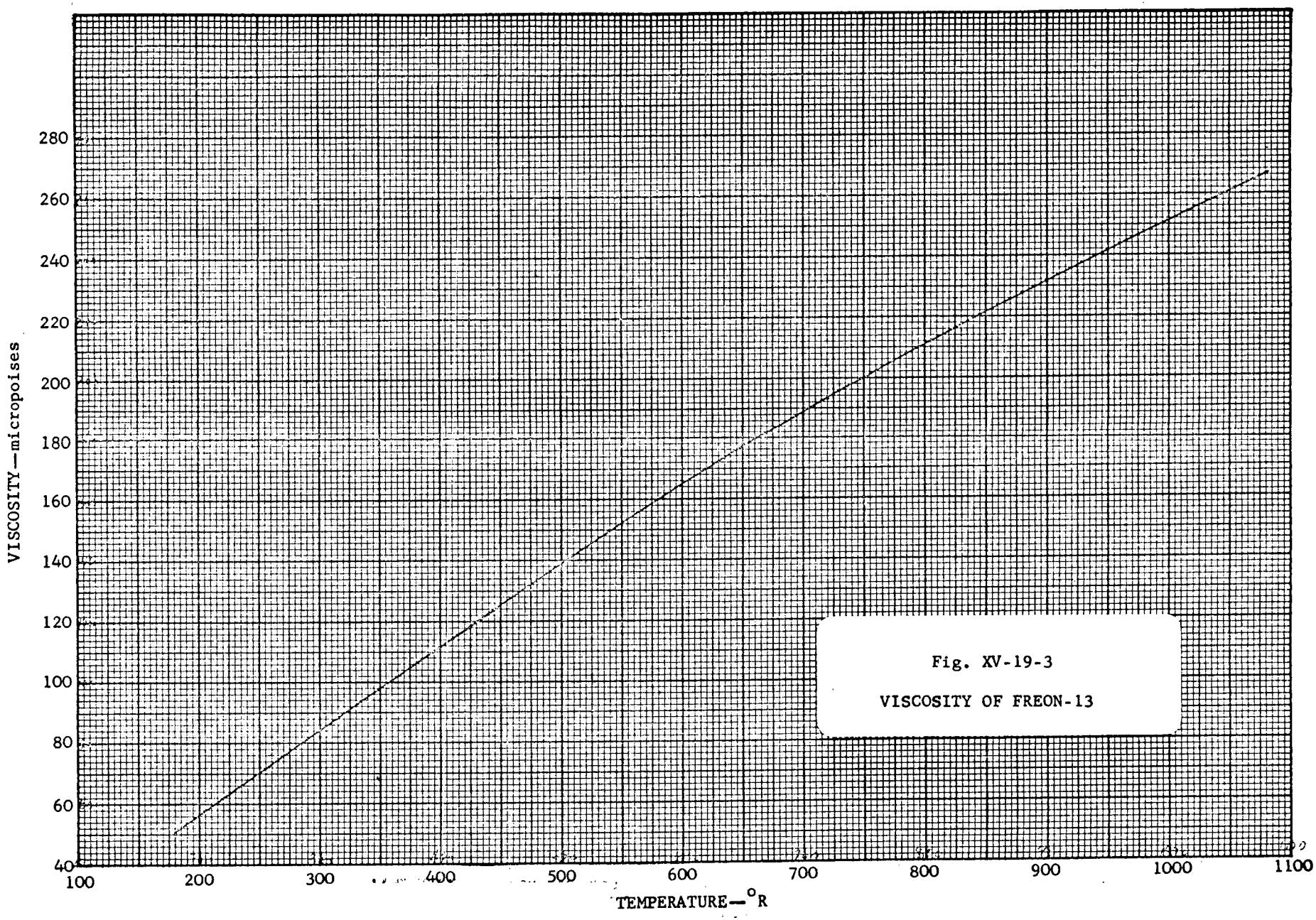


Fig. XV-19-3

VISCOSITY OF FREON-13

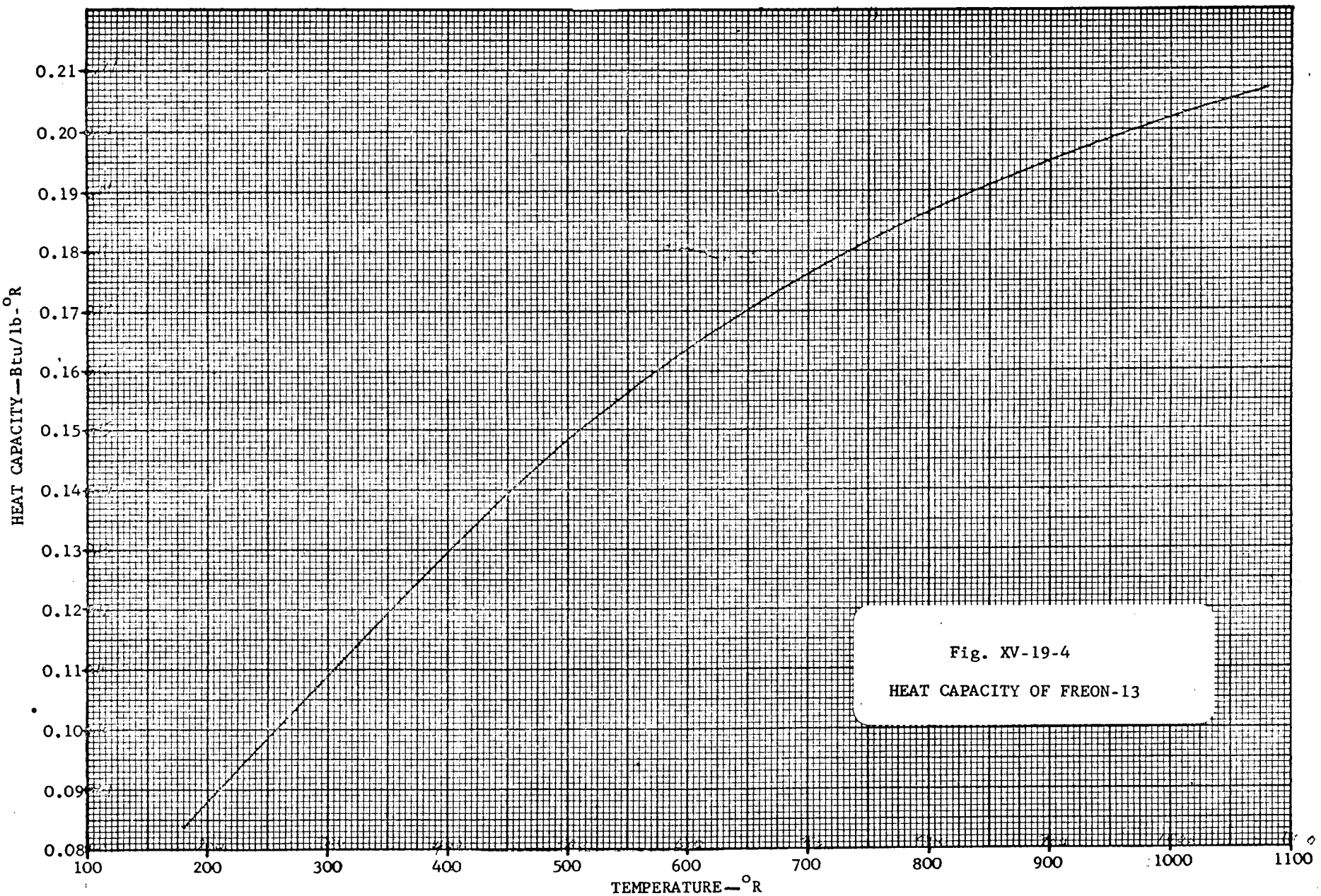


Fig. XV-19-4

HEAT CAPACITY OF FREON-13

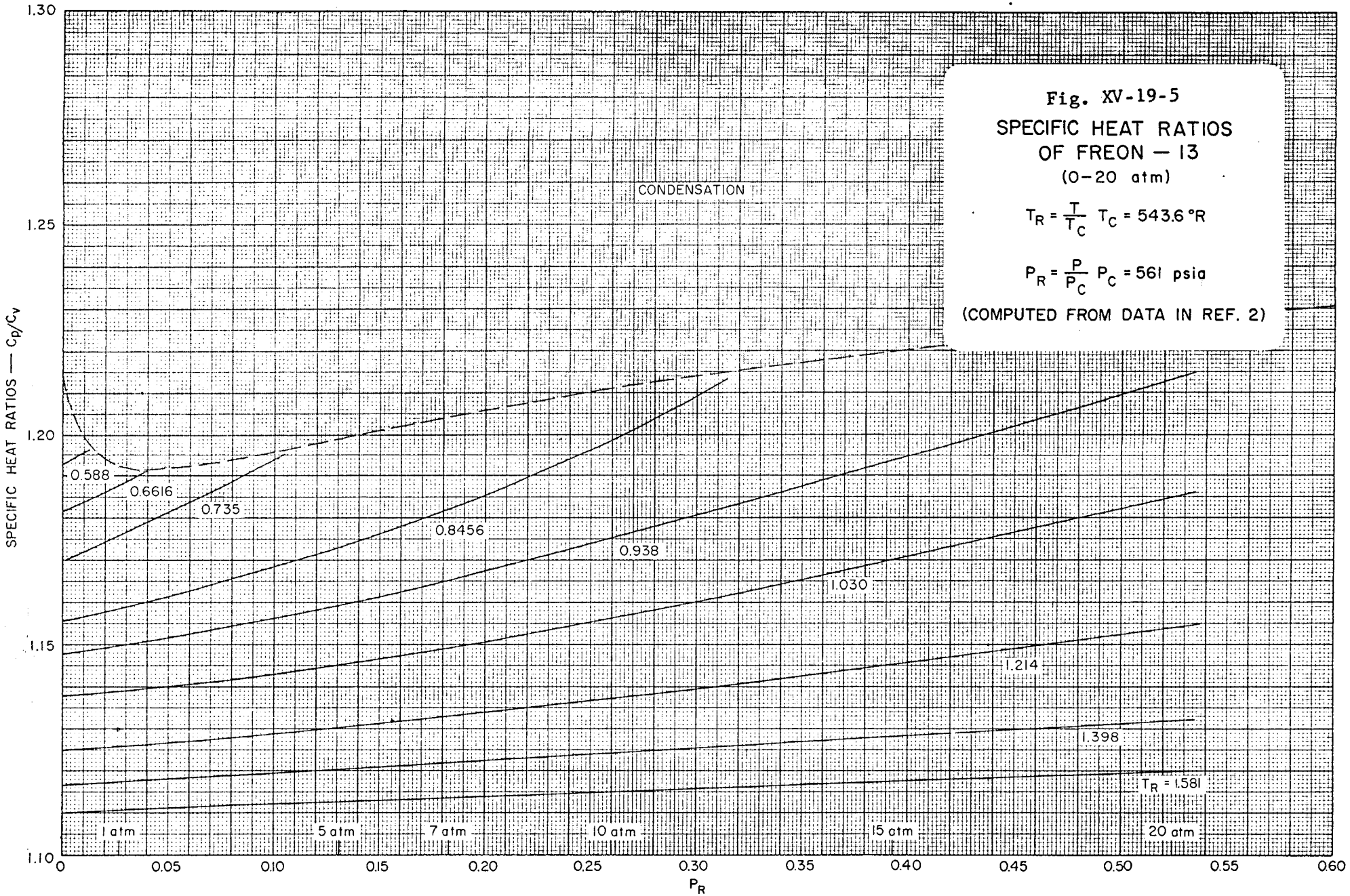


Fig. XV-19-5
SPECIFIC HEAT RATIOS
OF FREON — 13
(0–20 atm)
$T_R = \frac{T}{T_C}\ T_C = 543.6\ °R$
$P_R = \frac{P}{P_C}\ P_C = 561$ psia
(COMPUTED FROM DATA IN REF. 2)
CONDENSATION
0.588
0.6616
0.735
0.8456
0.938
1.030
1.214
1.398
$T_R = 1.581$
1 atm
5 atm
7 atm
10 atm
15 atm
20 atm
SPECIFIC HEAT RATIOS — C_p/C_v
P_R
1.30
1.25
1.20
1.15
1.10
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60

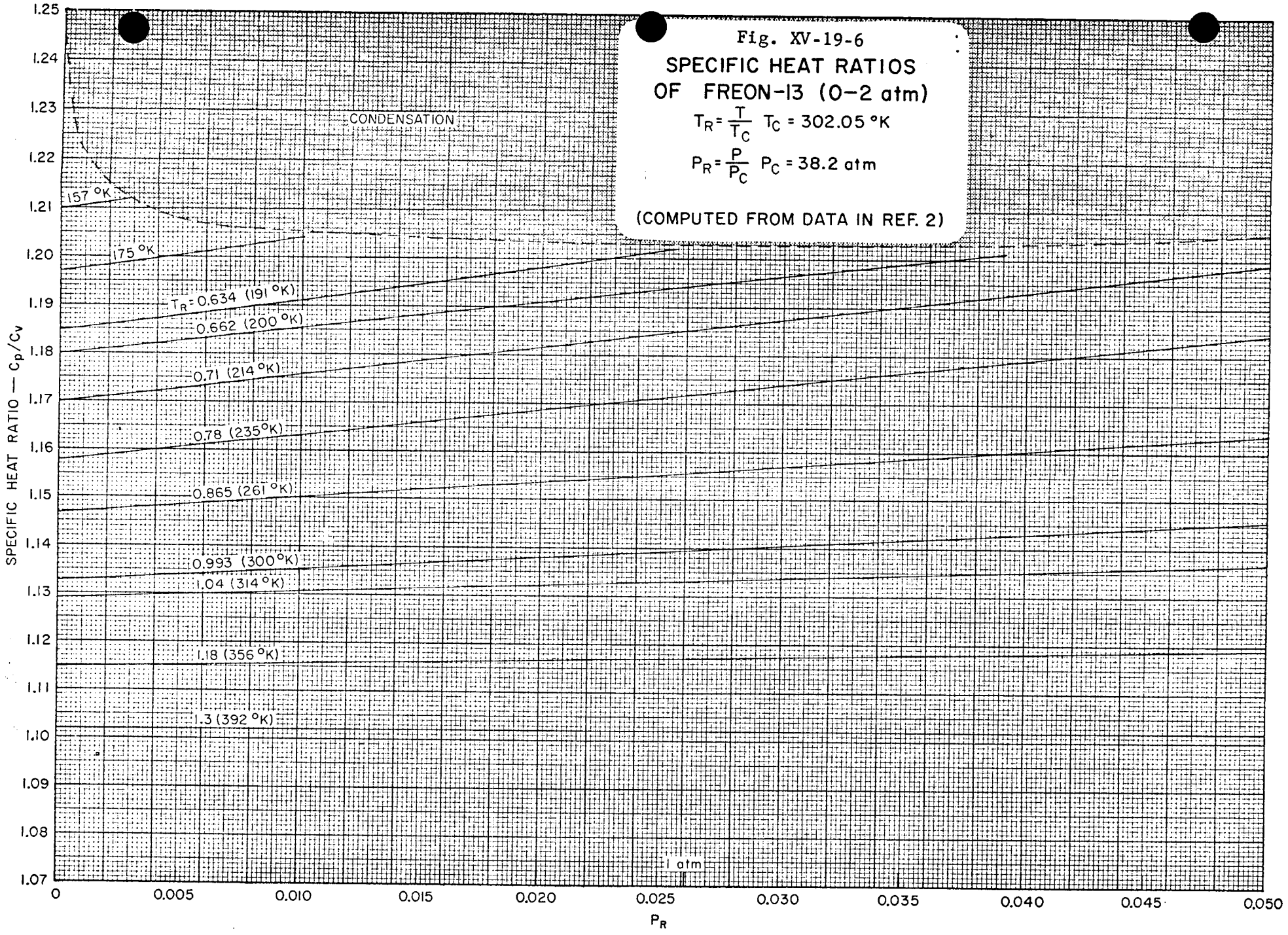


Fig. XV-19-6
SPECIFIC HEAT RATIOS
OF FREON-13 (0–2 atm)
$T_R = \frac{T}{T_C}$ T_C = 302.05 °K
$P_R = \frac{P}{P_C}$ P_C = 38.2 atm
(COMPUTED FROM DATA IN REF. 2)
CONDENSATION
157 °K
175 °K
T_R = 0.634 (191 °K)
0.662 (200 °K)
0.71 (214 °K)
0.78 (235 °K)
0.865 (261 °K)
0.993 (300 °K)
1.04 (314 °K)
1.18 (356 °K)
1.3 (392 °K)
1 atm
SPECIFIC HEAT RATIO — C_p/C_v
P_R
1.25
1.24
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
1.08
1.07
0
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
0.045
0.050

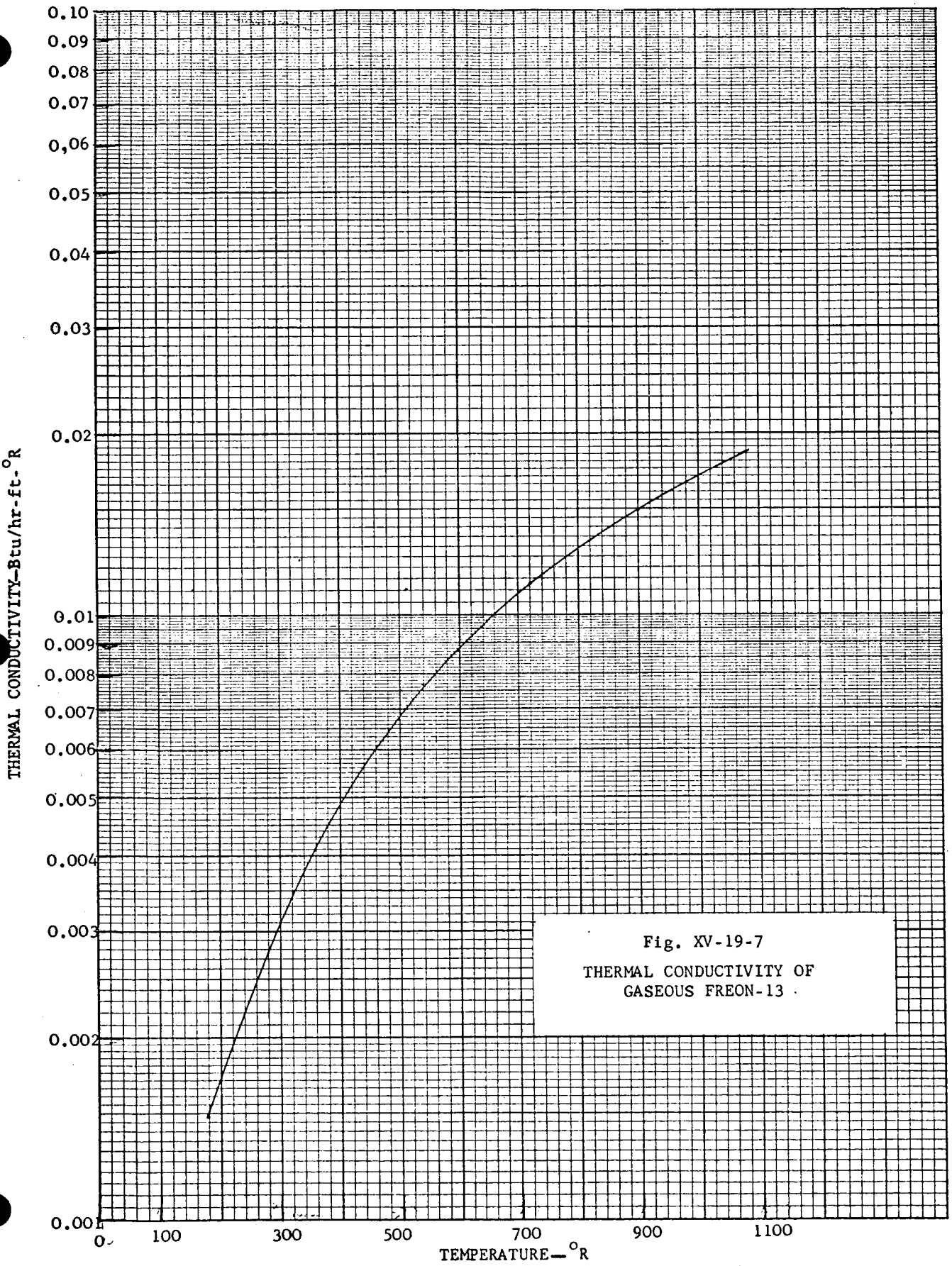


Fig. XV-19-7

THERMAL CONDUCTIVITY OF GASEOUS FREON-13

XV-19 FREON-13 REFERENCES

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2. Du Pont de Nemours, E.I. and Co. Tech. Bull. T-13.
3. Gelles, E. and Pitzer, K.S. J. ACS 75, p. 5259, 1953.
4. Svehla, R.A. NASA TR R-132, 1962.
5. Anon. (The Matheson Co., Inc., Matheson of Canada, Ltd., Whitby, Ontario) Matheson Gas Data Book. 1961.
6. Hodgman, C.D. (Ed.) Handbook of Chemistry and Physics (42nd edn.). Chemical Rubber Publishing Co., Cleveland, Ohio, 1960-61.

Table XV-20-1

PHYSICAL CONSTANTS

OF

FREON-14

		REF.
Molecular Weight	88.01	5
Boiling Point @ 1 atm	-198.4°F	5
Freezing Point @ 1 atm	-299.2°F	5
Specific Volume @ 70°F, 1 atm	4.4 cu ft/lb	5
Vapor Pressure @ -238.3°F	1.93 psia	5
Specific Gravity, Liquid @ -202°F	1.62	5
Density		
Liquid		
Gas		
Critical Temperature	-49.9°F	5
Critical Pressure	542.9 psia	5
Critical Density		
Latent Heat of Vaporization @ b.p.	58.64 Btu/lb	5
Latent Heat of Fusion		
Specific Heat of Gas		
c_p @ -112°F, 1 atm	0.132 Btu/lb-°F	5
c_v @ -112°F, 1 atm	0.1081 Btu/lb-°F	
Specific Heat Ratio, c_p/c_v @ -112°F	1.220	5
Thermal Conductivity @ -169°F	0.10 Btu/hr-ft-°F	5
Viscosity		
Liquid		
Gas		
Solubility in Water		
Surface Tension		

Table XV-20-1.1

SOME VALUES OF THE GAS CONSTANT, *R*, FOR FREON-14
(See also Conversion Tables, Section I)

TEMPERATURE IN °K				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.932357	0.963336	708.591	13.7020
mole/cm^3	82.0567	84.7832	62363.1	1205.91
mole/liter	0.0820544	0.0847809	62.3613	1.20587
lb/ft^3	0.0149348	0.0154310	11.3504	0.219482
lb/mole/ft^3	1.31441	1.35808	998.952	19.3166
TEMPERATURE IN °R				
Pressure / Density	atm	kg/cm^2	mm of Hg	lb/in^2
g/cm^3	0.517976	0.535187	393.662	7.61220
mole/cm^3	45.5871	47.1018	34646. 2	669.950
mole/liter	0.0455858	0.0471005	34.6452	0.669928
lb/ft^3	0.00829710	0.00857276	6.30579	0.121934
lb/mole/ft^3	0.730228	0.754489	554.973	10.7314

Table XV-20-2

VAPOR PRESSURE OF FREON-14 (Ref. 2)

TEMPERATURE		VAPOR PRESSURE	TEMPERATURE		VAPOR PRESSURE
°K	°R	psia	°K	°R	psia
127.59	229.67	3.463	183.15	329.67	117.4
133.15	239.67	5.726	188.70	339.67	147.49
138.70	249.67	9.050	194.26	349.67	182.8
144.26	259.67	13.75	199.82	359.67	223.8
147.82	269.67	20.17	205.37	369.67	271.2
155.37	279.67	28.69	210.93	379.67	325.7
160.93	289.67	39.72	216.48	389.67	388.4
166.48	299.67	53.67	222.04	399.67	460.6
172.04	309.67	70.97	227.04	408.67	535.8
177.59	319.67	92.07			

(See Figure XV-20-1)

Table XV-20-3

DENSITY OF FREON-14 (Ref. 2)

TEMP. °R \ PRESSURE psia	DENSITY-lb/ft^3								
	100	200	400	600	1000	1400	2000	4000	6000
280	(98.5)	(98.7)	(99.0)	(99.4)	(100.0)	(101.0)	(102.0)	-	-
320	(89.9)	(90.0)	(90.5)	(91.5)	(92.5)	(93.6)	(95.1)	(99.0)	-
360	2.532	5.872	(79.8)	(81.0)	(83.2)	(85.3)	(87.5)	(92.8)	(96.2)
400	2.208	4.833	13.07	(64.9)	(71.1)	(74.5)	(78.1)	(86.3)	(91.1)
440	1.967	4.177	9.737	18.62	49.02	56.82	61.35	(79.7)	(85.3)
480	1.777	3.705	8.157	13.74	30.39	45.25	53.48	(72.3)	(79.6)
520	1.624	3.344	7.128	11.45	22.17	34.60	46.76	(65.5)	(74.4)
560	1.496	3.055	6.382	10.01	18.25	27.55	40.16	(60.0)	(69.5)
600	1.388	2.818	5.804	8.969	15.80	23.15	34.25	(54.8)	(65.2)
640	(1.21)	2.617	5.339	8.170	14.06	20.28	29.76	49.02	(61.1)
680	(1.08)	(2.36)	4.953	7.513	12.77	18.18	26.39	46.08	(57.5)
720	(1.01)	(2.16)	(4.55)	6.978	11.74	16.56	23.75	43.29	(54.3)
760	(0.985)	(2.02)	(4.21)	6.527	10.89	15.24	21.74	40.65	(51.5)

(See Figure XV-20-2)

NOTE: (__) Data Extrapolated

Table XV-20-4

VISCOSITY OF FREON-14
(Ref. 4)

TEMPERATURE		ABSOLUTE VISCOSITY
°K	°R	micropoises
100	180	62.4
200	360	123.9
300	540	176.7
400	720	222.2
500	900	262.7
600	1080	299.6

(See Figure XV-20-3)

Table XV-20-5

HEAT CAPACITY OF FREON-14
(Ref. 3)

TEMPERATURE		HEAT CAPACITY
°K	°R	Btu/lb-°R
100	180	0.09431
150	270	0.1092
200	360	0.1286
250	450	0.1485
298.16	536.7	0.1660
300	540	0.1667
400	720	0.1969
500	900	0.2195
600	1080	0.2360

(See Figure XV-20-4)

Table XV-20-6

THERMAL CONDUCTIVITY
OF GASEOUS FREON-14
(Ref. 4)

TEMPERATURE		THERMAL CONDUCTIVITY
^{o}K	^{o}R	Btu/hr-ft-^{o}R
100	180	0.00203
200	360	0.00540
300	540	0.00990
400	720	0.0147
500	900	0.0193
600	1080	0.0237

(See Figure XV-20-5)

Table XV-20-7

SELECTED VALUES OF SATURATION PROPERTIES OF FREON-14 (Ref. 2)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-$^\circ$R	
$^\circ$R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
229.69	3.4630	0.009278	8.0017	107.780	0.12497	42.084	62.082	104.166	0.3552	0.6255
234.69	4.4802	0.009355	6.3041	106.893	0.15863	43.089	61.569	104.658	0.3595	0.6219
239.69	5.7264	0.009434	5.0230	105.996	0.19909	44.112	61.038	105.150	0.3638	0.6185
244.69	7.2372	0.009516	4.0441	105.087	0.24727	45.153	60.486	105.639	0.3681	0.6153
249.69	9.0503	0.009600	3.2877	104.166	0.30416	46.214	59.910	106.124	0.3724	0.6123
254.69	11.206	0.009687	2.6971	103.233	0.37077	47.294	59.313	106.606	0.3767	0.6096
259.69	13.748	0.009777	2.2311	102.286	0.44822	48.394	58.689	107.083	0.3809	0.6069
264.69	16.719	0.009869	1.8599	101.325	0.5377	49.517	58.036	107.554	0.3852	0.6045
269.69	20.168	0.009965	1.5620	100.350	0.6402	50.655	57.363	108.018	0.3894	0.6021
274.69	24.142	0.010065	1.3204	99.359	0.7574	51.823	56.650	108.473	0.3937	0.5999
279.69	28.690	0.010168	1.1232	98.352	0.8903	53.007	55.912	109.920	0.3979	0.5978
284.69	33.864	0.010275	0.9611	97.327	1.0405	54.214	55.142	109.356	0.4022	0.5959
289.69	39.716	0.010386	0.8268	96.283	1.2095	55.440	54.341	109.781	0.4064	0.5940
294.69	46.298	0.010502	0.7148	95.220	1.3990	56.687	53.506	110.193	0.4106	0.5922
299.69	53.665	0.010623	0.6209	94.135	1.6106	57.952	52.639	110.592	0.4148	0.5905
304.69	61.870	0.010750	0.5415	93.027	1.8466	59.242	51.732	110.974	0.4191	0.5888
309.69	70.969	0.010882	0.4742	91.895	2.1089	60.553	50.786	111.339	0.4233	0.5873
314.69	81.017	0.011021	0.4167	90.737	2.3998	61.880	49.807	111.687	0.4275	0.5857
319.69	92.070	0.011167	0.3674	89.549	2.7216	63.224	48.790	112.014	0.4316	0.5842
324.69	104.186	0.011321	0.3250	88.330	3.0774	64.585	47.735	112.320	0.4358	0.5828

Table XV-20-7 (contd)

SELECTED VALUES OF SATURATION PROPERTIES OF FREON-14 (Ref. 2)

TEMP.	PRESSURE	VOLUME—cu-ft/lb		DENSITY—lb/ft^3		ENTHALPY—btu/lb			ENTROPY—btu/lb-^{o}R	
^{o}R	psia	liquid	vapor	liquid	vapor	liquid	latent	vapor	liquid	vapor
329.69	117.42	0.011484	0.2881	87.076	3.4714	65.975	46.624	112.599	0.4399	0.5813
334.69	131.84	0.011657	0.2560	85.784	3.9064	67.380	45.472	112.852	0.4441	0.5799
339.69	147.49	0.011841	0.2280	84.449	4.3867	68.801	44.275	113.075	0.4482	0.5785
344.69	164.45	0.012038	0.2033	83.067	4.9184	70.244	43.021	113.265	0.4523	0.5771
349.69	182.77	0.012250	0.1816	81.632	5.5069	71.707	41.711	113.418	0.4564	0.5757
354.69	202.53	0.012479	0.1623	80.136	6.1610	73.197	40.331	113.528	0.4605	0.5742
359.69	223.81	0.012726	0.1451	78.569	6.8904	74.715	38.873	113.589	0.4646	0.5727
364.69	246.67	0.013000	0.1298	76.921	7.7053	76.258	37.337	113.595	0.4687	0.5711
369.69	271.21	0.013302	0.1160	75.174	8.6229	77.837	35.700	113.537	0.4728	0.5694
374.69	297.53	0.013641	0.1035	73.309	9.6656	79.464	33.936	113.399	0.4770	0.5676
379.69	325.74	0.014026	0.0920	71.296	10.8648	81.154	32.009	113.163	0.4813	0.5656
384.69	355.98	0.014474	0.0816	69.091	12.2609	82.917	29.891	112.808	0.4857	0.5634
389.69	388.39	0.015009	0.0718	66.625	13.9295	84.799	27.489	112.287	0.4904	0.5609
394.69	423.18	0.015679	0.0625	63.780	15.9949	86.858	24.674	111.532	0.4954	0.5579
399.69	460.61	0.016582	0.0534	60.307	18.7266	89.236	21.158	110.394	0.5011	0.5540
404.69	501.01	0.018013	0.0438	55.514	22.8519	92.278	16.212	108.490	0.5083	0.5484
409.50 (Critical)	543.16	0.025602	0.0256	39.060	39.0600	100.636	0.000	100.636	0.5284	0.5284

V = volume in cu-ft/lb
H = enthalpy in btu/lb
S = entropy in btu/lb-°R
(saturation properties in (parentheses)

Table XV-20-8.1

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 10, 30, 60 psia (Ref. 2)

TEMPERATURE	10 psia (sat'n temp. 252.00°R)			30 psia (sat'n temp. 281.02°R)			60 psia (sat'n temp. 303.60°R)		
°R	V	H	S	V	H	S	V	H	S
259.69	3.0949	107.2158	0.6144						
269.69	3.2211	108.3622	0.6188						
279.69	3.3471	109.5285	0.6230						
289.69	3.4726	110.7148	0.6272	1.1159	110.0973	0.6010			
299.69	3.5979	111.9211	0.6313	1.1602	111.3359	0.6052			
309.69	3.7230	113.1476	0.6353	1.2042	112.5917	0.6094	0.5724	111.6918	0.5918
319.69	3.8478	114.3941	0.6393	1.2479	113.8650	0.6134	0.5962	113.0154	0.5960
329.69	3.9725	115.6607	0.6432	1.2914	115.1562	0.6174	0.6198	114.3521	0.6001
339.69	4.0969	116.9474	0.6470	1.3347	116.4655	0.6213	0.6430	115.7020	0.6042
349.69	4.2212	118.2542	0.6508	1.3779	117.7930	0.6251	0.6660	117.0665	0.6081
359.69	4.3453	119.5809	0.6545	1.4208	119.1391	0.6289	0.6889	118.4462	0.6120
369.69	4.4693	120.9276	0.6582	1.4636	120.5037	0.6327	0.7115	119.8418	0.6158
379.69	4.5932	122.2941	0.6619	1.5063	121.8870	0.6364	0.7340	121.2535	0.6196
389.69	4.7170	123.6804	0.6655	1.5489	123.2889	0.6400	0.7563	122.6818	0.6233
399.69	4.8407	125.0864	0.6690	1.5913	124.7096	0.6436	0.7785	124.1270	0.6270
409.69	4.9643	126.5120	0.6726	1.6336	126.1490	0.6472	0.8006	125.5892	0.6306
419.69	5.0877	127.9572	0.6760	1.6759	127.6071	0.6507	0.8226	127.0685	0.6342
429.69	5.2112	129.4217	0.6795	1.7181	129.0838	0.6542	0.8445	128.5652	0.6377
439.69	5.3345	130.9056	0.6829	1.7601	130.5792	0.6576	0.8663	130.0794	0.6412
449.69	5.4578	132.4087	0.6863	1.8022	132.0932	0.6610	0.8881	131.6110	0.6446
459.69	5.5810	133.9308	0.6896	1.8441	133.6257	0.6644	0.9097	133.1601	0.6480

Table XV 20-8.1 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 10, 30, 60 psia

TEMPERATURE	10 psia (sat'n temp. 252.00°R)			30 psia (sat'n temp. 281.02°R)			60 psia (sat'n temp. 303.60°R)		
°R	V	H	S	V	H	S	V	H	S
469.69	5.7041	135.4718	0.6930	1.8860	135.1767	0.6677	0.9313	134.7268	0.6514
479.69	5.8272	137.0318	0.6962	1.9278	136.7460	0.6710	0.9529	136.3109	0.6547
489.69	5.9503	138.6105	0.6995	1.9696	138.3336	0.6743	0.9744	137.9126	0.6580
499.69	6.0733	140.2078	0.7027	2.0114	139.9394	0.6775	0.9958	139.5318	0.6613
509.69	6.1963	141.8235	0.7059	2.0531	141.5632	0.6808	1.0172	141.1684	0.6646
519.69	6.3192	143.4576	0.7091	2.0947	143.2051	0.6840	1.0385	142.8224	0.6678
529.69	6.4421	145.1099	0.7123	2.1363	144.8647	0.6871	1.0598	144.4937	0.6710
539.69	6.5649	146.7802	0.7154	2.1779	146.5421	0.6903	1.0811	146.1822	0.6741
549.69	6.6878	148.4684	0.7185	2.2193	148.2366	0.6934	1.1023	147.8878	0.6772
559.69	6.8105	150.1744	0.7216	2.2608	149.9492	0.6965	1.1235	149.6105	0.6803
569.69				2.3023	151.6791	0.6995	1.1446	151.3501	0.6834
579.69				2.3437	153.4263	0.7026	1.1658	153.1065	0.6865
589.69				2.3852	155.1905	0.7056	1.1869	154.8797	0.6895
599.69							1.2079	156.6694	0.6925
609.69							1.2290	158.4757	0.6955

Table XV-20-8.2

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 100, 160, 250 psia (Ref. 2)

TEMPERATURE	100 psia (sat'n temp. 323.01°R)			160 psia (sat'n temp. 343.42°R)			250 psia (sat'n temp. 365.39°R)		
°R	V	H	S	V	H	S	V	H	S
329.69	0.3491	113.1675	0.5862						
339.69	0.3647	114.5902	0.5904						
349.69	0.3800	116.0189	0.5946	0.2165	114.2118	0.5803			
359.69	0.3949	117.4547	0.5986	0.2276	115.7776	0.5847			
369.69	0.4097	118.9023	0.6026	0.2383	117.3337	0.5890	0.1318	114.4066	0.5731
379.69	0.4243	120.3602	0.6065	0.2487	118.8895	0.5932	0.1406	116.2358	0.5780
389.69	0.4386	121.8290	0.6103	0.2588	120.4419	0.5972	0.1489	118.0123	0.5826
399.69	0.4528	123.3127	0.6141	0.2687	121.9985	0.6011	0.1567	119.7516	0.5870
409.69	0.4669	124.8102	0.6178	0.2786	123.5661	0.6050	0.1642	121.4643	0.5912
419.69	0.4809	126.3229	0.6214	0.2881	125.1359	0.6088	0.1714	123.1713	0.5953
429.69	0.4948	127.8500	0.6250	0.2975	126.7167	0.6125	0.1784	124.8644	0.5993
439.69	0.5085	129.3920	0.6285	0.3069	128.3110	0.6162	0.1852	126.5596	0.6032
449.69	0.5222	130.9493	0.6320	0.3160	129.9138	0.6198	0.1919	128.2527	0.6070
459.69	0.5358	132.5231	0.6355	0.3251	131.5300	0.6233	0.1984	129.9484	0.6108
469.69	0.5493	134.1120	0.6389	0.3342	133.1601	0.6268	0.2048	131.6518	0.6144
479.69	0.5627	135.7170	0.6423	0.3431	134.8014	0.6303	0.2111	133.3609	0.6180
489.69	0.5762	137.3408	0.6457	0.3520	136.4586	0.6337	0.2173	135.0781	0.6216
499.69	0.5895	138.9785	0.6490	0.3608	138.1295	0.6371	0.2235	136.8052	0.6251
509.69	0.6027	140.6327	0.6522	0.3696	139.8142	0.6404	0.2296	138.5424	0.6285

Table XV-20-8.2 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 100, 160, 250 psia

TEMPERATURE	100 psia (sat'n temp. 323.01°R)			160 psia (sat'n temp. 343.42°R)			250 psia (sat'n temp. 365.39°R)		
°R	V	H	S	V	H	S	V	H	S
519.69	0.6159	142.3033	0.6555	0.3782	141.5121	0.6437	0.2356	140.2904	0.6319
529.69	0.6292	143.9926	0.6587	0.3869	143.2282	0.6470	0.2416	142.0533	0.6353
539.69	0.6423	145.6964	0.6619	0.3955	144.9576	0.6502	0.2474	143.8220	0.6386
549.69	0.6554	147.4166	0.6651	0.4041	146.7016	0.6534	0.2532	145.6051	0.6418
559.69	0.6684	149.1530	0.6682	0.4126	148.4615	0.6566	0.2590	147.4033	0.6451
569.69	0.6815	150.9058	0.6713	0.4211	150.2387	0.6598	0.2648	149.2141	0.6483
579.69	0.6945	152.6769	0.6744	0.4295	152.0264	0.6629	0.2705	151.0378	0.6515
589.69	0.7075	154.4613	0.6774	0.4379	153.8314	0.6660	0.2762	152.8734	0.6546
599.69	0.7204	156.2627	0.6805	0.4463	1555.6516	0.6690	0.2818	154.7250	0.6577
609.69	0.7333	158.0800	0.6835	0.4546	157.4868	0.6721	0.2874	156.5899	0.6608
619.69	0.7463	159.9155	0.6864	0.4629	159.3371	0.6751	0.2930	158.4684	0.6638
629.69	0.7591	161.7649	0.6894	0.4712	161.2024	0.6781	0.2986	160.3604	0.6669
639.69				0.4795	163.0854	0.6810	0.3041	162.2661	0.6699
649.69				0.4878	164.9811	0.6840	0.3096	164.1863	0.6729
659.69							0.3151	166.1201	0.6758
669.69							0.3206	168.0677	0.6787

Table XV-20-8.3

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 500, 800, 1000 psia (Ref. 2)

TEMPERATURE	500 psia (sat'n temp. 404.57°R)			800 psia			1000 psia		
°R	V	H	S	V	H	S	V	H	S
409.69	0.0522	111.6765	0.5562						
419.69	0.0613	115.2005	0.5647						
429.69	0.0682	117.9411	0.5712						
439.69	0.0740	120.3511	0.5767	0.0271	106.7678	0.5399	0.0204	101.6236	0.5263
449.69	0.0792	122.6038	0.5818						
459.69	0.0840	124.7359	0.5865	0.0387	115.7763	0.5600	0.0258	109.4247	0.5436
469.69	0.0886	126.8043	0.5909						
479.69	0.0928	128.8228	0.5952	0.0475	121.9844	0.5732	0.0329	116.8093	0.5594
489.69	0.0969	130.8018	0.5993						
499.69	0.1009	132.7662	0.6032	0.0546	127.1147	0.5837	0.0393	122.9348	0.5719
509.69	0.1047	134.7120	0.6071						
519.69	0.1084	136.6419	0.6108	0.0607	131.7776	0.5928	0.0451	128.3244	0.5825
529.69	0.1121	138.5743	0.6145						
539.69	0.1156	140.4962	0.6181	0.0664	136.1973	0.6012	0.0502	133.2256	0.5917
549.69	0.1191	142.4223	0.6217						
559.69	0.1226	144.3510	0.6251	0.0716	140.4797	0.6090	0.0548	137.8695	0.6002
569.69	0.1260	146.2804	0.6286						
579.69	0.1293	148.2124	0.6319	0.0766	144.7212	0.6164	0.0592	142.3601	0.6081
589.69	0.1325	150.1514	0.6352						
599.69	0.1358	152.1031	0.6385	0.0813	148.9056	0.6235	0.0633	146.7578	0.6155
609.69	0.1390	154.0609	0.6417						
619.69	0.1422	156.0258	0.6449	0.0859	153.0763	0.6304	0.0672	151.1003	0.6226
629.69	0.1453	157.9986	0.6481						
639.69	0.1484	159.9810	0.6512	0.0903	157.2490	0.6370	0.0711	155.4538	0.6296
649.69	0.1515	161.9751	0.6543						
659.69	0.1546	163.9786	0.6574	0.0946	161.4343	0.6434	0.0747	159.7735	0.6362
669.69	0.1576	165.9919	0.6604						
679.69	0.1606	168.0154	0.6634	0.0988	165.6396	0.6497	0.0783	164.0972	0.6427
689.69	0.1636	170.0514	0.6664						
699.69	0.1665	172.0987	0.6693	0.1029	169.8704	0.6559	0.0818	168.4337	0.6490
709.69	0.1695	174.1568	0.6722						

Table XV-20-8.3 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 800, 1000 psia

TEMPERATURE	800 psia			1000 psia		
°R	V	H	S	V	H	S
719.69	0.1069	174.1304	0.6619	0.0852	172.7895	0.6551
739.69	0.1108	178.4221	0.6677	0.0885	177.1690	0.6611
759.69	0.1148	182.7689	0.6735	0.0918	181.5758	0.6670
779.69	0.1187	187.1372	0.6792	0.0950	186.0120	0.6727
799.69	0.1225	191.5428	0.6848	0.0982	190.4794	0.6784
819.69	0.1262	195.9861	0.6903	0.1013	194.9788	0.6840
839.69	0.1300	200.4672	0.6957	0.1044	199.5109	0.6894
859.69	0.1336	204.9858	0.7010	0.1074	204.0758	0.6948
879.69	0.1373	209.5416	0.7062	0.1105	208.7012	0.7001
899.69	0.1409	214.1338	0.7114	0.1135	213.3391	0.7053
919.69	0.1445	218.7618	0.7165	0.1165	218.0102	0.7105
939.69	0.1481	223.4245	0.7215	0.1195	222.7137	0.7155
959.69	0.1517	228.1208	0.7264	0.1224	227.4489	0.7205
979.69	0.1552	232.8497	0.7313	0.1253	232.2148	0.7254
999.69	0.1587	237.6097	0.7361	0.1282	237.0103	0.7303
1019.69	0.1622	242.3995	0.7409	0.1311	241.8341	0.7350
1039.69	0.1657	247.2176	0.7456	0.1340	246.6850	0.7398
1059.69	0.1691	252.0626	0.7502	0.1368	251.5616	0.7444
1079.69	0.1726	256.9327	0.7547	0.1396	256.4623	0.7490
1099.69	0.1760	261.8263	0.7592	0.1424	261.3857	0.7535
1119.69	0.1795	266.7583	0.7637	0.1452	266.3301	0.7580
1139.69	0.1829	271.6973	0.7680	0.1480	271.2938	0.7623
1159.69	0.1863	276.6549	0.7723	0.1508	276.2751	0.7667

Table XV-20-8.4

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 2000, 2800, 4000 psia (Ref. 2)

TEMPERATURE	2000 psia			2800 psia			4000		
°R	V	H	S	V	H	S	V	H	S
439.69	0.0163	96.5847	0.5074						
459.69	0.0175	102.7516	0.5211	0.0163	101.8640	0.5138			
479.69	0.0187	107.9442	0.5322	0.0172	107.1639	0.5251			
499.69	0.0200	112.8590	0.5423	0.0179	111.8678	0.5347			
519.69	0.0214	117.6249	0.5516	0.0187	116.3872	0.5436			
539.69	0.0231	122.4691	0.5608	0.0196	120.7944	0.5519			
559.69	0.0249	127.3608	0.5697	0.0204	125.1696	0.5599			
579.69	0.0270	132.4020	0.5785	0.0214	129.6301	0.5677			
599.69	0.0292	137.4176	0.5870	0.0223	134.0190	0.5751			
619.69	0.0314	142.3978	0.5952	0.0235	138.7142	0.5828	0.0200	138.1795	0.5743
639.69	0.0336	147.3201	0.6030	0.0247	143.3587	0.5902	0.0204	142.2026	0.5807
659.69	0.0358	152.1823	0.6105	0.0260	148.0562	0.5974	0.0211	146.6017	0.5875
679.69	0.0379	156.9920	0.6177	0.0274	152.9688	0.6048	0.0217	150.9627	0.5940
699.69	0.0400	161.8564	0.6247	0.0289	157.8263	0.6118	0.0223	155.3511	0.6004
719.69	0.0421	166.6313	0.6315	0.0303	162.7085	0.6187	0.0231	160.0393	0.6070
739.69	0.0441	171.3922	0.6380	0.0317	167.6039	0.6254	0.0239	164.6623	0.6133
759.69	0.0460	176.1474	0.6443	0.0331	172.5062	0.6320	0.0246	169.3515	0.6196

Table XV-20-8.4 (contd)

PROPERTIES OF SUPERHEATED VAPOR OF FREON-14 AT 2000, 2800, 4000 psia

TEMPERATURE	2000 psia			2800 psia			4000 psia		
°R	V	H	S	V	H	S	V	H	S
779.69	0.0479	180.9035	0.6505	0.0346	177.4124	0.6383	0.0255	174.0987	0.6257
799.69	0.0498	185.6657	0.6565	0.0360	182.3218	0.6446	0.0264	179.0303	0.6320
819.69	0.0516	190.4382	0.6624	0.0373	187.2352	0.6506	0.0273	183.9377	0.6380
839.69	0.0534	195.2241	0.6682	0.0388	192.2542	0.6567	0.0282	188.8939	0.6440
859.69	0.0551	200.0258	0.6738	0.0402	197.2079	0.6625	0.0291	193.8913	0.6499
879.69	0.0569	204.8450	0.6794	0.0415	202.1739	0.6682	0.0300	198.9235	0.6557
899.69	0.0586	209.6830	0.6848	0.0428	207.1536	0.6738	0.0310	203.9851	0.6614
919.69	0.0603	214.5404	0.6902	0.0441	212.1480	0.6793	0.0319	209.0717	0.6670
939.69	0.0619	219.4176	0.6954	0.0454	217.1577	0.6847	0.0329	214.1801	0.6725
959.69	0.0637	224.3749	0.7006	0.0467	222.1834	0.6900	0.0338	219.3077	0.6779
979.69	0.0653	229.3059	0.7057	0.0479	227.2252	0.6952	0.0347	224.4521	0.6832
999.69	0.0669	234.2584	0.7107	0.0492	232.2831	0.7003	0.0356	229.6117	0.6884
1019.69	0.0685	239.2318	0.7157	0.0504	237.3568	0.7053	0.0365	234.7849	0.6935
1039.69	0.0701	244.2253	0.7205	0.0516	242.4459	0.7103	0.0374	239.9704	0.6985
1059.69	0.0717	249.2382	0.7253	0.0528	247.5498	0.7151	0.0384	245.2909	0.7036
1079.69	0.0733	254.2695	0.7300	0.0540	252.6676	0.7199	0.0393	250.5214	0.7085
1099.69	0.0748	259.3180	0.7346	0.0552	257.7984	0.7246	0.0402	255.8733	0.7133
1119.69	0.0764	264.3824	0.7392	0.0564	262.9412	0.7293	0.0411	261.0154	0.7180
1139.69	0.0779	269.4616	0.7437	0.0575	268.0947	0.7338	0.0420	266.2765	0.7227
1159.69	0.0795	274.5539	0.7481	0.0587	273.2577	0.7383	0.0429	271.5453	0.7273

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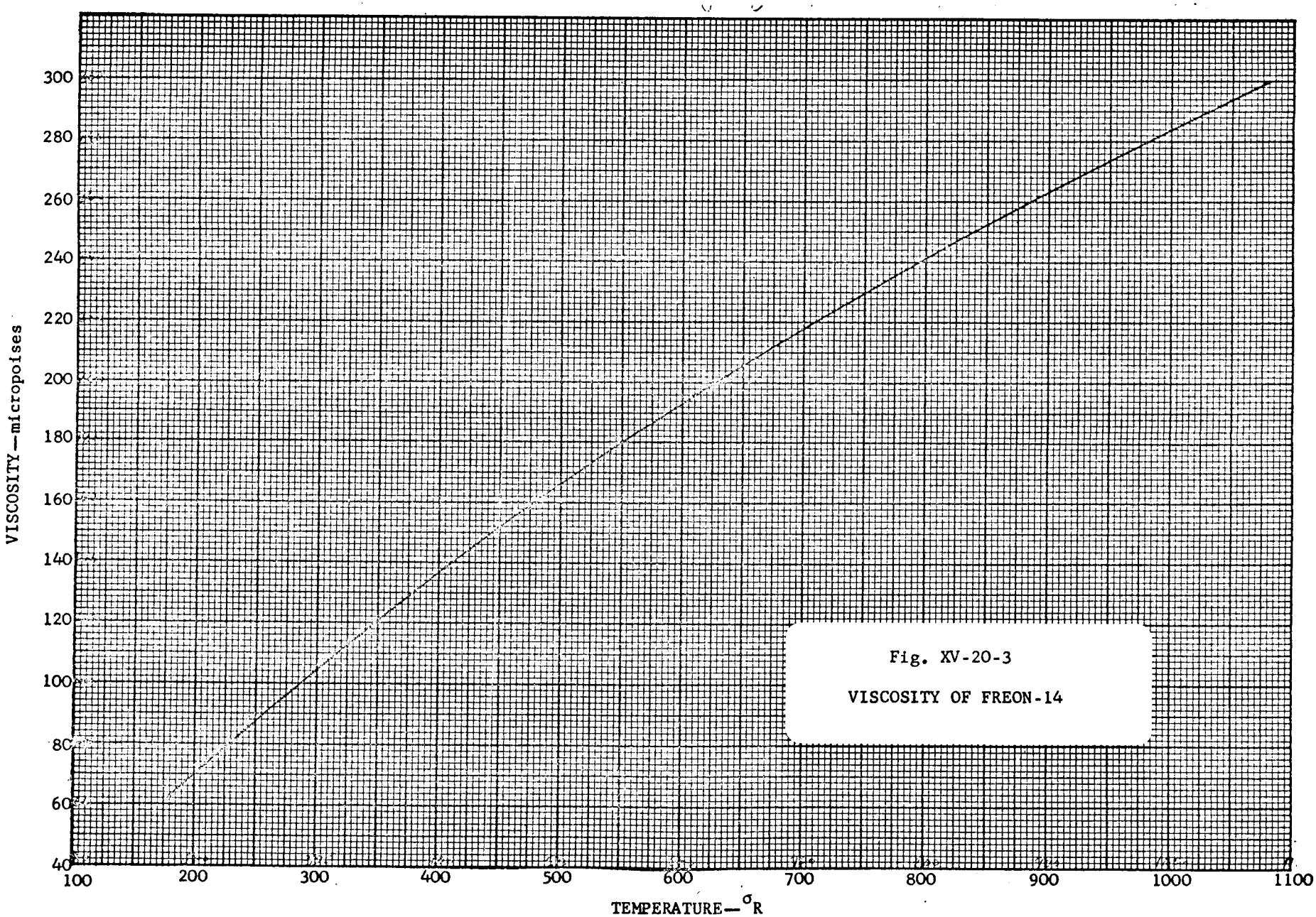

Fig. XV-20-3

VISCOSITY OF FREON-14

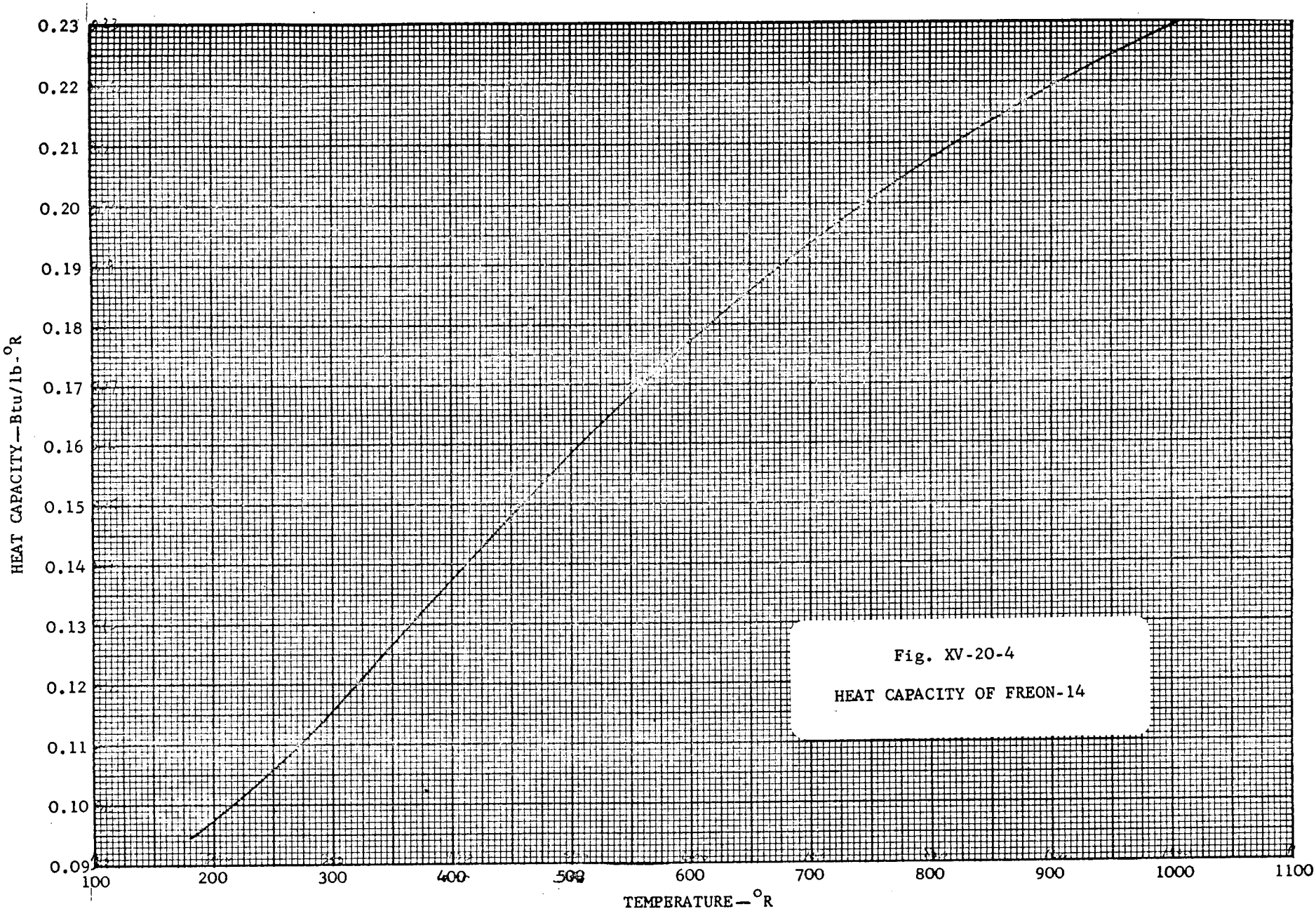

Fig. XV-20-4

HEAT CAPACITY OF FREON-14

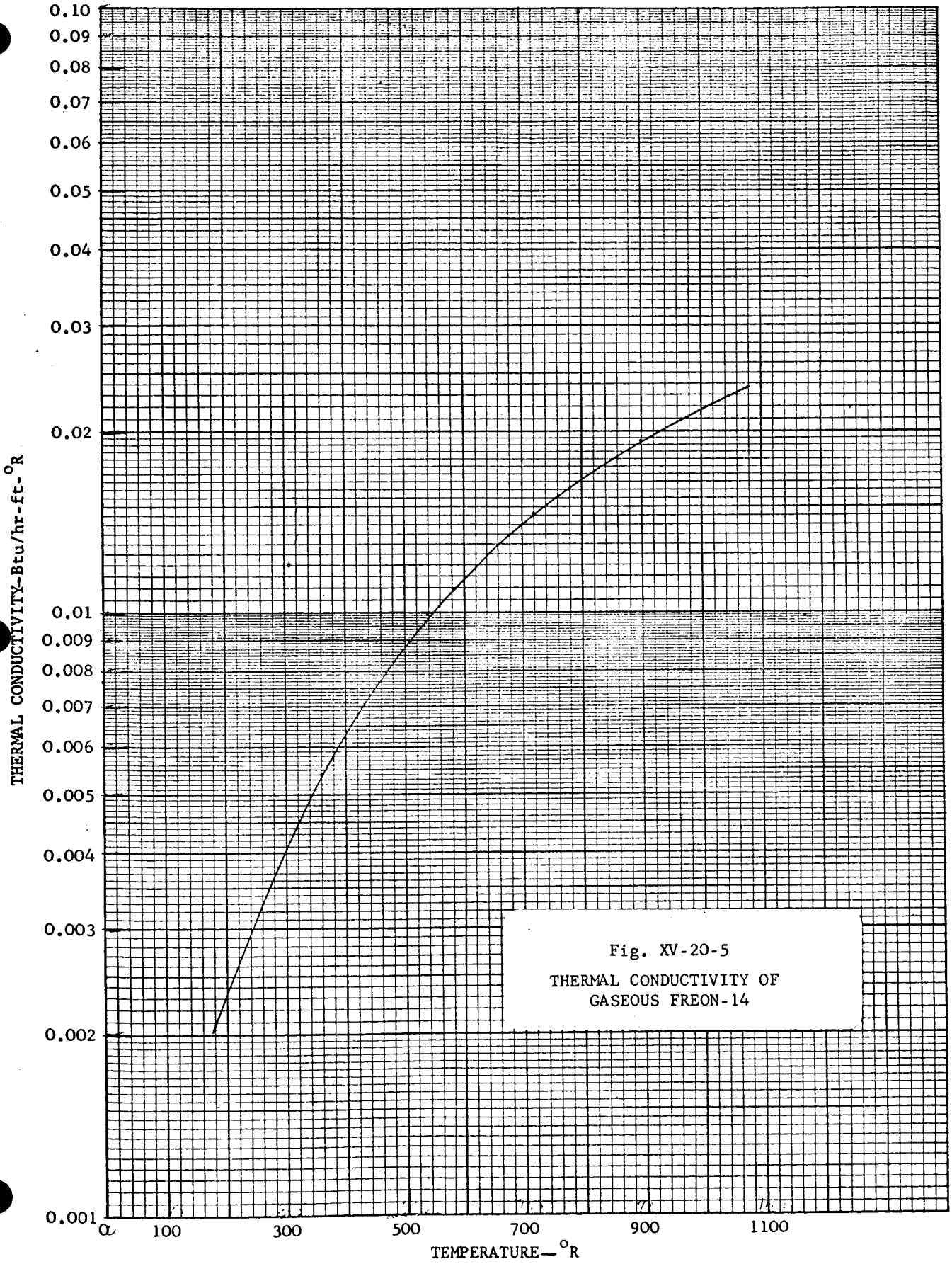

Fig. XV-20-5

THERMAL CONDUCTIVITY OF GASEOUS FREON-14