FLUKE ®

Calibration

RUSKA 2485

Hydraulic Piston Gauge

Users Manual

PN 3974967
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Chapter 1
Introduction and Specifications

Introduction

This manual covers the operation and maintenance of the RUSKA 2485 Hydraulic Piston Gauge.

How to Contact Fluke

To order accessories, receive operating assistance, or get the location of the nearest Fluke distributor or Service Center, call:

- Technical Support USA: 1-800-99-FLUKE (1-800-993-5853)
- Calibration/Repair USA: 1-888-99-FLUKE (1-888-993-5853)
- Canada: 1-800-36-FLUKE (1-800-363-5853)
- Europe: +31-402-675-200
- China: +86-400-810-3435
- Japan: +81-3-3434-0181
- Singapore: +65-738-5655
- Anywhere in the world: +1-425-446-5500

Or, visit Fluke's website at www.fluke.com.

To register your product, visit http://register.fluke.com.

To view, print, or download the latest manual supplement, visit http://us.fluke.com/usen/support/manuals.

Safety Information

⚠ Warning

Pressurized vessels and associated equipment are potentially dangerous. The apparatus described in this manual should be operated only by personnel trained in procedures that will assure safety to themselves, to others, and to the equipment.

⚠ Warning

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

⚠ Warning

Do not exceed safe maximum generated pressures as follows:

2485-930	**20,000 PSI, 1,400 bar**
2485-950	**Hand Pump System - 20,000 PSI, 1,400 bar**
2485-950	**Main Housing & Test Port Manifold — 72,500 PSI, 5,000 bar**

Always use replacement parts specified by Fluke.

When any maintenance is performed, turn off power and remove power cord.

Caution: Do not mix fluid types.
Fluid types available: Spinesstic 22 oil, dioctyl sebacate (DOS).

Do not exceed the safe working pressures for the test port manifold adapters. Refer to markings on the adapters and to Figure 4-2 for safe operating pressure.

Symbols Used in this Manual

In this manual, a **Warning** identifies conditions and actions that pose a hazard to the user. A **Caution** identifies conditions and actions that may damage the Hydraulic Piston Gauge or the equipment under test.

Symbols used on the Pressure Calibration System and in this manual are explained in Table 1-1.

Table 1-1. Symbols

Symbol	Description
~	AC (Alternating Current)
⏚	Earth Ground
⚠	Important Information: refer to manual
(crossed-out wheeled bin)	Do not dispose of this product as unsorted municipal waste. Go to Fluke's website for recycling information.

General Specifications

Instrument Pressure Range	2485-930 0.5 to 1,375 bar; 7.25 to 20,000 psi 2485-950 0.5 to 5,000 bar; 7.25 to 72,500 psi (gauge mode pressures; referenced to ambient atmospheric pressure)
Safety Test Pressure	1.5 times the system working pressure for low pressure system 1.25 times the system working pressure for high pressure system
Pressure Media	Spinesstic 22 oil (S22) Dioctyl Sebacate oil (DOS)

Accuracy Class*	Pressure accuracy to 0.0025% reading from 6% of full scale to full scale and 0.0003% of full scale below 6%, traceable to U.S. National Institute of Standards and Technology.
Instrument Platform Dimensions	Height: 50.8 cm (20 in.) including mass stack (72 cm/20 in. with high pressure extension) Width: 50.8 cm (20 in.) Depth: 35.6 cm (14 in.) excluding hand pump Handle Weight: 40 kg.
Electrical Requirements	115 or 230 vac, 50 or 60 Hz, switchable
Temperature Range	Operation: 18 ºC to 28 ºC Storage:-20 ºC to 50 ºC when thermometer is removed.
Humidity Range	Operation: 20% to 75% Storage: 0% to 90%

Piston/Cylinder Specifications

Sensitivity Threshold	0.0001% reading (1 ppm)
Repeatability	0.0003% reading (3 ppm)
Reproducibility	0.0006% reading per year (6 ppm)
Piston/Cylinder Material	Cemented Tungsten Carbide, 6% Cobalt
Thermal Coefficient	9.1 x 10^{-6} in^2/in^2/deg C (9.1 ppm per deg C)
Cylinder Configuration	Simple, Minimal Mounting Stress
Maximum Sink Rate	See Table 1-1

*Refer to Table 1-2 for a sample error analysis.

Table 1-2. Piston/Cylinder Selection

Unit-Increment Designation	Nominal Pressure Increment & Unit of Measure	Minimum Pressure	Optimum Performance Range	Pressure Medium	Model Number	Maximum Sink Rate mm/Inches	Uncertainty Capability
P10	10 psi/Kg	10	60 - 1000 psi	DOS	2485-981	0.5/0.02	0.0025
P100	100 psi/Kg	100	600 - 10000 psi	DOS	2485-982	0.5/0.02	0.0035
P200	200 psi/Kg	200	1200 - 20000 psi	DOS	2485-983	0.5/0.02	0.0035
P600	600 psi/Kg	900	3900 - 60000 psi	DOS	2485-997	1.0/0.04	0.01
B 0.5	0.5 bar/Kg	0.5	3 - 50 bar	DOS	2485-984	0.5/0.02	0.0025
B5	5 bar/Kg	5	30 - 500 bar	DOS	2485-985	0.5/0.02	0.0035
B10	10 bar/Kg	10	60 - 1000 bar	DOS	2485-986	0.5/0.02	0.0035
B50	50 bar/Kg	75	325 - 5000 bar	DOS	2485-989	1.0/0.04	0.01
P10	10 psi/Kg	10	60 - 1,000 psi	S22	2485-991	0.5/0.02	0.0025

Table 1-3. Piston/Cylinder Selection, continued.

Unit-Increment Designation	Nominal Pressure Increment & Unit of Measure	Minimum Pressure	Optimum Performance Range	Pressure Medium	Model Number	Maximum Sink Rate mm/Inches	Uncertainty Capability
P100	100 psi/Kg	100	600 - 10000 psi	S22	2485-992	0.5/0.02	0.0035
P200	200 psi/Kg	200	1200 - 20000 psi	S22	2485-993	0.5/0.02	0.0035
B0.5	0.5 bar/Kg	0.5	3 - 50 bar	S22	2485-994	0.5/0.02	0.0025
B5	5 bar/Kg	5	30 - 500 bar	S22	2485-995	0.5/0.02	0.0035
B10	10 bar/Kg	10	60 - 1000 bar	S22	2485-996	0.5/0.02	0.0035

Mass Set Specifications

Mass Material	Nonmagnetic austenitic (300 series) stainless steel
Storage case Dimensions (Masses Included)	First Case: Height: 33.7 cm (13.2 in.) Width: 33.0 cm (13 in.) Depth: 25.4 cm (10 in.) Weight: 16 kg (35 lb.) Other Cases: Height: 31.8 cm (12.5 in.) Width: 33.0 cm (13 in.) Depth: 20.3 cm (8 in.) Weight: 23 kg (50 lb.)
Mass Denominations	1 each 1.9 kg, hanger mass* 19 each 5.0 kg, large platters 1 each 3.0 kg, small platter 1 each 2.0 kg, small platter 1 each 1.0 kg, small platter 1 each 0.5 kg, small platter 1 each 0.3 kg, small platter 1 each 0.2 kg, small platter 1 each 0.1 kg to 0.01 g, trim set**
Adjustment Tolerance	Each mass in the set is completely machined to the nominal kilogram mass denomination (apparent mass versus brass standards, e.g. 8.4 g/cm^3) to within the adjustment tolerance of 15 ppm, or 3.0 x 10^{-6} kilogram, whichever is greater. Nominal values within this tolerance are traceable to the U.S. National Institute of Standards and Technology.
Mass Identification	Each mass in the set is permanently marked with the serial number of the set, a sequence number, and the nominal mass denomination.
Calibration Tolerance	All masses are calibrated using precision balances and are traceable to the U.S. National Institute of Standards and Technology. Individual mass values are reported to an uncertainty to 5 ppm, or 5.0e-07 kilogram, whichever is greater.

*Total tare; includes mass of piston, mass loading table and compensator.

**Optional Class "S-1" Laboratory Mass Set

Chapter 2
Piston Pressure Gauge

Measurement Considerations

Measurements of pressure using a piston pressure gauge are limited by disturbances resulting from various influences including environmental effects and operating procedures, as well as certain physical aspects of the equipment. The effects of these disturbances can be reduced by exercising control over the influence, or by measuring the effects and applying corrections. Some of the factors that influence pressure measurements are below.

- Elastic distortion of the piston/cylinder assembly
- Piston/cylinder temperature
- Gravitational acceleration
- Atmospheric buoyancy
- Pressure gradients
- Float position of height
- Surface tension
- Vertical alignment of piston axis

Pressure results from the application of a force onto an area. Numerically, it is the quotient of the force divided by the area onto which it is applied:

$$P = F / A$$

where

P = pressure,

F = force, and

A = cross-sectional area.

Some of the influences stated above have a direct effect on the area of the piston/cylinder assembly, while other factors affect the force or the pressure. Corrections based on these influences are described accordingly in the following sections. Two final equations combining all the corrections are described at the end of the section — one equation for computing the mass required to generate a desired pressure, and a second for computing the pressure generated for a given load. As there are many engineering units established for pressure measurements, it is important to ensure that the units affixed to each parameter used in the computations are matched to the engineering pressure unit desired. Further explanation and worksheets are included in Appendix A.

Effective Area of the Piston/Cylinder Assembly

Types of Piston Pressure Gauges

The piston pressure gauge is sometimes regarded as an absolute instrument because of the principle by which it measures pressure. An absolute instrument is defined here as one capable of measuring a quantity in the fundamental units of mass, length, time, etc. It may be suggested that only certain types of piston pressure gauges qualify in this category.

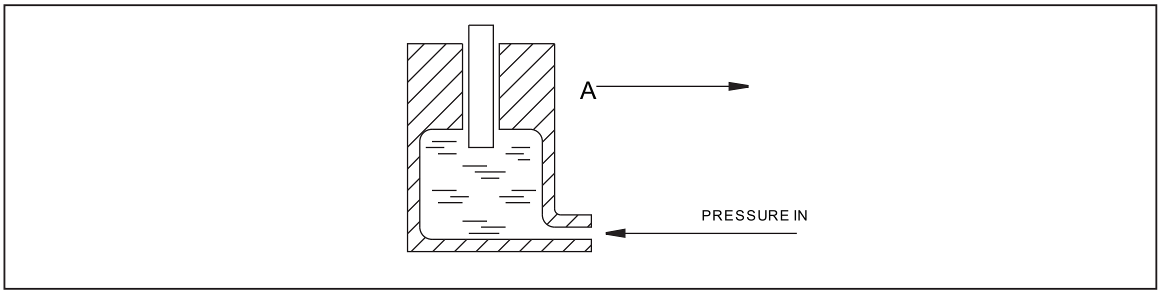

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Figure 2-1. Simple Cylinder

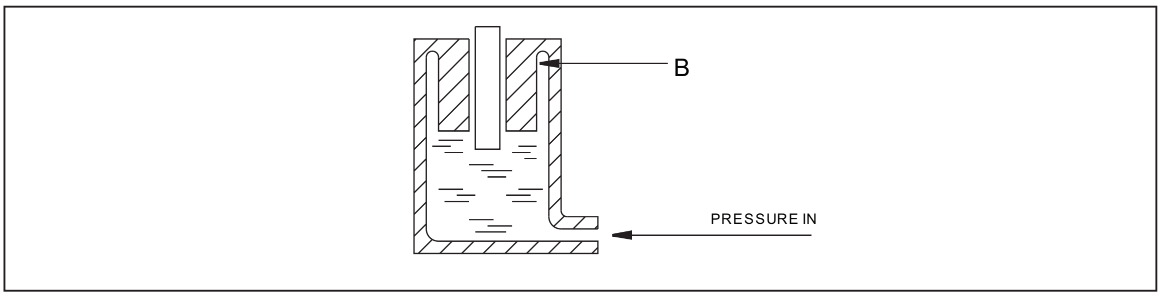

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Figure 2-2. Re-Entrant Cylinder

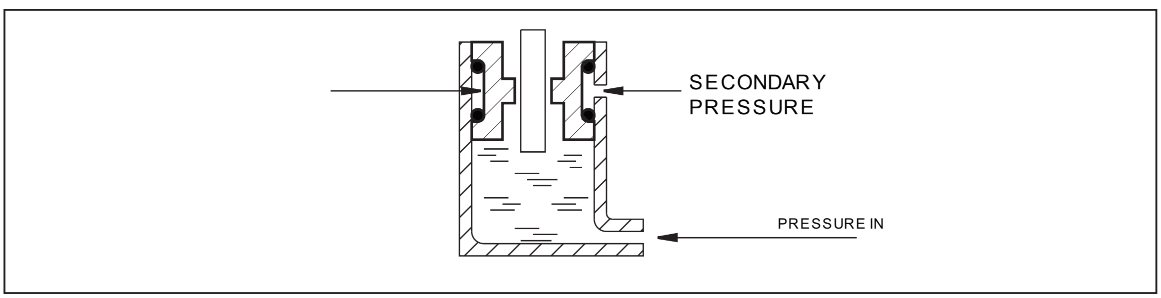

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Figure 2-3. Controlled Clearance Cylinder

Figures 2-1, 2-2 and 2-3 illustrate the three most common types of cylinder arrangements.

When the simple cylinder of Figure 2-1 is subjected to an increase in pressure, the fluid, exerting a relatively large total force, normal to the surface of confinement, expands the cylinder wall near Point A and results in an elastic dilation of the cylinder bore. As the pressure is increased, the cylinder expands and the effective area increases. The change in effective area is usually a linear function of the applied pressure. The piston also suffers distortion from the pressure of the operating fluid but to a much lesser extent than the cylinder. It is evident, the, that the simple cylinder of Figure 2-1 would be inadequate for a primary piston pressure gauge unless some reliable means of predicting the change in area were available.

The increase in the effective area of the simple cylinder is also accompanied by an increase in the leakage of the fluid past the piston. Indeed, the leakage becomes so great that at some pressure the floating time will not be sufficient for an accurate pressure measurement.

In Figure 2-2, the pressure fluid is allowed to surround the body of the cylinder. The pressure drop occurs across the cylinder wall near the top of the cylinder, at B, but in the opposite direction to that of the simple cylinder in Figure 2-1. In consequence, the elastic distortion is directed toward the piston, tending to decrease the effective area of the assembly.

Again, the change in the area with pressure places a limit on the usefulness of the re-entrant cylinder as a primary instrument. Some benefit does result however from the use of the re-entrant cylinder because higher pressures may be attained without a loss in float time. A small sacrifice is made in the float time at lower pressures because the total clearance between piston and cylinder is generally greater with a simple cylinder design.

In the controlled-clearance design of Figure 2-3, the cylinder is surrounded by a chamber to which a secondary pressure system is connected. Adjustment of the secondary, or chamber pressure, permits the operator to change the clearance between the cylinder and piston at will. A series of observations involving piston sink rates at various jacket pressures leads to the empirical determination of the effective area of the assembly.

High performance piston pressure gauges may be constructed using simple or re-entrant cylinders. Determination of the distortion coefficients and effective area of such gauges may be made by direct comparison with a controlled-clearance gauge. Although elastic distortion affects all types of piston pressure gauges, the magnitude may be small enough that it can be ignored.

Elastic Distortion of the Piston/Cylinder Assembly

As the pressure is increased within a piston pressure gauge, the resulting stress produces a temporary and reversible deformation of the piston/cylinder components. The result is a change in the effective area of the piston/cylinder assembly. If the change in the area is a linear function of the applied pressure, the relationship may be described by the equality:

$$A_e = A_o \left(1 + b\rho\right)$$

where

A_e	=	Effective area at pressure p ,
A_0	=	Effective area of the piston-cylinder assembly at zero pressure,
b	=	Coefficient of elastic distortion; the fractional change in area per unit of pressure, and
ρ	=	Nominal system pressure acting on the piston/cylinder assembly.

For higher pressure instruments, the pressure effect may be non-linear and is commonly expressed by the equality:

$$A_e = A_o \left(1 + b_1\rho + b_2\rho^2\right)$$

where

A_e	=	Effective area at pressure p ,
A_0	=	Effective area of the piston/cylinder assembly at zero pressure,
b_1	=	Coefficient of elastic distortion as a function of pressure, the fractional change in area per unit of pressure, and
b_2	=	Coefficient of elastic distortion as a function of the square of the pressure, the fractional change in area per unit of pressure squared.
ρ^2	=	Square of nominal system pressure

Temperature

Piston pressure gauges are temperature sensitive and, for accurate measurements, corrections must be applied for deviations from the reference temperature. When the temperature of a piston/cylinder assembly is above the reference temperature, the effective area will be larger than at the reference temperature and the pressure for a given load will be less. When the temperature of the piston/cylinder assembly is below the reference, the effective area will be smaller and the pressure for the same load will be greater. Depending on the magnitude, these thermal changes may have a significant effect on the measurements. Corrections for temperature are applied at the time of a measurement using the following relation:

$$A_{e(t)} = A_{e(r)} \left(1 + C\left(t - r\right)\right)$$

where

$A_{e(t)}$	=	Effective area corrected to working temperature,
$A_{e(r)}$	=	Effective area at the reference temperature,
C	=	Coefficient of thermal expansion; the fractional change in area per unit of temperature,
t	=	Piston/cylinder working temperature, and
r	=	Piston/cylinder reference temperature

The thermal coefficient for a piston/cylinder assembly is directly dependent on the materials used. The appropriate value for the coefficient as well as the reference temperature, are listed in the calibration report for the piston/cylinder assembly. Some typical thermal coefficients and materials are shown in the following table; refer to the calibration report for actual values.

Table 2-1. Typical Thermal Coefficients

Piston Material	Cylinder Material	Thermal Coefficient (per degrees Celsius)
WC*	WC	9.1×10^{-6}
Steel	WC	1.5×10^{-5}
Steel	Steel	2.0×10^{-5}

*WC = Tungsten Carbide

Force

Gravitational Acceleration

Pressure is a function of force per unit area. Any action that affects the force applied to the piston proportionally affects the pressure generated with the piston. Masses applied to a piston are accelerated in a downward direction by the gravitational attraction of the earth thereby exerting a force on the piston. Gravitational acceleration varies from location to location, thus, so do the forces exerted on the piston by a given mass. The gravitational acceleration at different locations within the continental United States, and the resulting variations in pressure for a piston pressure gauge, vary by more than 0.17 per cent. Corrections for these gravitational variances are performed according to the following equality:

$$F = M\left(G_1 / G_s\right)$$

where

F	=	Downward force,
M	=	Mass of object,
G_1	=	Local Gravitational Acceleration in m/s^2, and
G_S	=	Standard Gravitational Acceleration, 9.80665 m/s^2.

Cosine Error

It is important to note that the gravitational effect is in a vertical direction. If the axial motion of the piston is not vertical, the force acting on the piston, and hence the pressure generated, is reduced as a function of the cosine of the angular deviation from vertical. This situation is often referred to as a cosine error, but can be corrected for using the following equation:

$$F_a = F\ \cos\theta$$

where

F_a	=	axial force acting on the piston,
F	=	vertical force, and
θ	=	angular deviation of piston axis from vertical.

An angular displacement of 0.25 degrees from vertical results in a reduction in pressure of approximately 10 parts per million. Since a significant deviation from vertical may also affect the performance of a deadweight gauge, it is common to adjust the piston to vertical within a fraction of a degree using a sensitive spirit level (typically attached to the instrument base) rather than measure the angle and applying corrections.

Buoyant Effect of the Air

Archimedes' principle shows that the vertical force exerted by an object submerged in a fluid is reduced by an amount equal to the mass of the fluid displaced. The magnitude of this buoyant force can be determined as a function of the volume of the object and the density of the fluid displaced. Since the volume of an object can be determined as a function of its mass and density, and the volumes of masses used on a piston gauge are usually not measured directly, it is common to determine the buoyant force due to the air surrounding the masses as a function of the density of the objects and the ambient air as follows:

$$F_b = F\ (1 - D_a / D_m)$$

where

F_b	=	Resultant Vertical Force,
F	=	Original Vertical Force,
D_a	=	Air Density (nominally 0.0012 g/cm^3), and
D_m	=	Mass Reference Density.

For most piston gauges, the mass values are usually reported in units of "apparent mass versus brass standards*" or "apparent mass versus stainless steel*" and True Mass. If the load on a piston is comprised of various materials, with various densities, buoyancy corrections, using True Mass values, would be computed individually for each type of material. A single correction to the entire load however, can be made by using apparent mass values and substituting the reference density (8.4 g/cm^3 for apparent mass versus brass, and typically 8.0 g/cm^3 for apparent mass versus stainless steel) for the true density in the buoyancy correction.

As with the piston/cylinder assembly, temperature affects the dimensions of the masses. These dimensional changes result in volume changes, and hence, buoyancy changes. The nominal volumetric thermal coefficient for a typical steel used in piston gauge masses is approximately 45 x 10^{-6} per degrees Celsius, has only a very small effect, and is typically ignored in piston pressure gauge applications.

Changes in air density resulting from barometric, temperature and relative humidity changes can be significant to piston pressure gauge measurements. Appendix A includes tables and equations for computing air density based on these parameters. Even though the environmental conditions vary continuously, the range is usually relatively small. Often, average barometer, temperature, and relative humidity values are used for calculating air density, and the typical environmental variations are accounted for in the estimate of uncertainty.

Some piston pressure gauges incorporate a reference chamber for evacuating much of the air surrounding the load on the piston. In this "absolute" mode of operation, the air remaining in the reference chamber usually has an insignificant buoyant effect on the masses, although the actual pressure (typically near 100 mTorr, or 0.002 psi) may be a substantial portion of the total pressure and should be added to the piston pressure. Further, because the buoyant force is not significant, the "true mass" values should be used. It is important to note that under extreme evacuation there may be additional considerations, as well as the potential for a reduced level of performance and an increase in uncertainty.

*Refer to reference number 4 for further discussion of apparent mass.

Combined Gravity and Air Buoyancy Correction

If the effects of varying ambient conditions are within acceptable limits (as determined by an error budget), it becomes convenient to combine the air buoyancy and gravitational corrections into one term, K, used as a conversion between mass and force. For gauge mode operation, the conversion is between force and apparent mass. For absolute mode operation, where nearly all the air is removed from around the masses such that the buoyant effect is typically insignificant, the conversion is between force and true mass:

$$K = \left(1 - D_a / D_m\right) G_1 / G_s$$

where

K	=	Mass-force conversion factor
D_a	=	Air density,
D_m	=	Mass reference density,
G_1	=	Local gravitational acceleration in m/s^2, and
G_S	=	Standard gravitational acceleration, 9.80665 m/s^2.

Surface Tension

For many hydraulic deadweight gauges, the surface tension of the pressure medium acting on the piston exerts a downward force that is significant to some pressure measurements. The effects of surface tension are commonly included in the total mass value provided for the tare components, but may be applied as a separate correction.

Pressure Corrections and Other Miscellaneous Factors

Hydraulic Fluid Pressure Gradients

When gravity acts on a column of fluid, such as in a liquid manometer, a pressure is generated at the bottom of the column nominally equal to the height of the column multiplied by the density of the fluid. The same pressure gradient exists in a hydraulic deadweight gauge calibration system. For two different positions within the calibration system, a difference in pressure exists that is nominally equal to the density of the fluid multiplied by the vertical separation between the two positions. The horizontal separation between these positions has no influence on the pressure gradient. The correction for the pressure head can be accomplished using the following equation:

$$H = h\, D_f \;\; G_1 / G_s$$

where

H	=	Head pressure,
h	=	Column height (positive value if the test device reference plane is higher than the reference plane of the standard,
D_f	=	Pressure fluid density,
G_1	=	Local gravitational acceleration in m/s^2, and
G_S	=	Standard gravitational acceleration (9.80665 m/s^2); not used for S.I. units.

The density of a fluid increases as a function of pressure. The increased density results in a greater head pressure for a given column height. With most hydraulic systems, the change in fluid density is so small, relative tot he magnitude of the system pressure required to change the fluid density, that hydraulic head corrections are usually not adjusted for different system pressures and the density of the fluid is usually treated as a constant. Further, because head corrections are typically relatively small, temperature and gravity adjustments to fluid head corrections are typically ignored. However, it is recommended that the influences are calculated thereby allowing the user to determine if they are to be ignored or included in the total system error budget.

The datum for pressure head corrections when using a hydraulic deadweight gauge is generally located at a position near the bottom of the piston/cylinder assembly. This vertical position is often referred to as the horizontal plane of reference, as all positions within the system in the same horizontal plane will have the same pressure. This position is usually selected (for convenience) so that the effects of fluid buoyancy on the submerged portion of the piston and the pressure head correction for that position cancel and can be ignored. This position is located at the physical bottom of a piston of uniform geometry. For other piston styles where, for example, there is an enlargement on the bottom of the piston, such as a retaining nut, the reference plane position is somewhat below the physical bottom of the piston assembly at a position where the bottom of the assembly would be if the nut was the same diameter as the piston while conserving the volume.

Pneumatic Pressure Gradients

In the same way as pressure heads are generated in a hydraulic system, they also are prevalent in pneumatic systems. The two important differences between hydraulic and pneumatic system pressure heads are that the magnitude of the pneumatic system corrections tend to be significantly less (at lease at lower pressures) than in a hydraulic system, and that, unlike the relatively constant hydraulic head, the magnitude of the gas head changes significantly with pressure due to the relative high compressibility and resulting density increase associated with gases. For further information on pneumatic pressure head corrections refer to the tables included in Appendix A.

Reference Pressure Head

For very low pressure devices referenced to atmosphere, and some low pressure differential devices where both the test port and the reference port are pressurized, a further correction may be necessary to account for a difference in the reference pressure acting on the test device and the standard. For a device referenced to atmosphere and positioned above the standard, the atmospheric pressure acting on the reference port of the test device will be less than that acting on the standard. For normal air density this correction equates to approximately 5.2×10^{-4} psi per foot (1.18×10^{-2} KPa per meter). The correction is in the opposite direction of the system pressure head correction, but is of a constant magnitude and hence, will be most significant at the lower calibration pressures.

The reference pressure head correction can be simplified by assuming nominal equality of the density of the system gas and the reference pressure gas (atmosphere). Then, using a system gas density for a gauge pressure taken from a chart for absolute pressures, the result will likely be beyond the performance of all but the most sensitive devices.

Float Position

The optimum operating position of a piston pressure gauge is known as mid-float. This position, near mid-stroke of the piston, is the calibrated position and the position where pressure head corrections will be valid. Significant deviations from this position can result in head pressure errors, but will likely result in greater errors as a result of slight variations in the taper or other geometric aspect of the piston or cylinder of a given assembly. Typically, the pressure in a system is adjusted to obtain a float position slightly above mid-float and the normal leakage of the pressure medium through the clearance between the piston and cylinder will allow the piston to slowly descend through the mid-float position. Assuming adequate time has been allowed for thermal stabilization and no significant leaks are present in the system, this is the time when a measurement should be made.

Minimum Pressure

For most piston pressure gauges there is a minimum pressure that can be generated by floating the piston. This tare pressure is that which is required to float the minimum load on the deadweight gauge, which may be the piston alone. Although there is usually a substantial degradation in uncertainty (percent of reading) at tare pressure, it is often required as a calibration point. It is also, however, one of the most frequently overlooked considerations in the operation of a deadweight gauge, and one that if ignored in tabulating the total piston load, will result in a substantial error.

Pressure to Mass Equation

Some measurement condition may require that a specific pressure be generated. The exact load required to generate such a pressure can be computed from the following equation that combines the corrections described in the previous sections. Step-by-step instructions and worksheets are also included in Appendix A.

$$M = \frac{\left(P_{dut} + H - R\right)\ A_{e(t)}}{K}$$

where

M	=	Total mass required on piston (apparent mass for gauge mode, true mass for absolute mode) to generate the desired pressure (includes tare mass and surface tension),
P_{dut}	=	Pressure at reference plane of device under test,
H	=	Head pressure (Chapter 2, Hydraulic Fluid Pressure Gradients),
R	=	Reference pressure (absolute mode; typically 100 mTorr),
$A_{e(t)}$	=	Effective area corrected to working temperature, (see Chapter 2, effective Area of the Piston/Cylinder Assembly), and
k	=	Mass=force conversion factor (see Chapter 2, Force).

Mass to Pressure Equation

Some measurement condition may require that a load be applied to the deadweight gauge to measure an unknown pressure. The exact pressure generated for a given load can be computed from the following equation that combines the corrections described in the previous sections. Step-by-step instructions and worksheets are also included in Appendix A.

$$P_{dut} = \frac{M \ \ K}{A_{e(t)}} + R - H$$

where

P_{dut}	=	Pressure at reference plane of device under test,
M	=	Total mass loaded on the piston (apparent mass for gauge mode, true mass for absolute mode) to generate the pressure (includes tare mass and surface tension),
k	=	Mass-force conversion factor,
$A_{e(t)}$	=	Effective area corrected to working temperature,
R	=	Reference pressure (absolute mode; typically 100 mTorr), and
H	=	Head pressure.

Conditions Favorable For a Measurement

Precision pressure measurements using a deadweight gauge can only be made when all miscellaneous disturbances, such as vibration, air drafts, and personnel traffic, have been minimized or eliminated. Further, if an operator is inadequately trained in the proper operation of the equipment, or whose judgment is impaired by distractions or other influences, there is discernible risk of personal injury and damage of delicate instrumentation.

When operating a precision deadweight piston gauge, one concern is the amount of time available to make a measurement. The major influence on the time available to make a measurement is the amount of time the piston remains in the region near the calibrated mid-float position. This "float" time is directly dependent on the sink rate of the piston; the rate at which the piston descends into the cylinder displacing the fluid that leaks through the annular clearance provided to lubricate the piston.

There are several conditions of normal operation of a deadweight gauge that temporarily bias the sink rate. When a volume of fluid, gas or oil, is compressed, a sudden rise occurs in the temperature of the fluid. As this heat dissipates into the surrounding containment, the temperature of the fluid is reduced and the pressure decreases accordingly. If the containment is a deadweight piston gauge, the piston will rapidly descend into the cylinder resulting in an unusually high sink rate until such a time as the fluid and containment reach thermal equilibrium. This thermal, or adiabatic effect, is bi-directional.

When the fluid is depressurized it undergoes a sudden decrease in temperature. As the fluid absorbs heat from the containment, the resulting sink rate will be abnormally low until the system again reaches equilibrium. In fact, this effect may result in a rise in float position. Depending on factors such as volume, rate of pressurization, internal surface area of the system, and fluid characteristics, the time required for equilibration may exceed 30 minutes. Typically, however, only 5 to 10 minutes are required for adequate operation of the deadweight gauge.

Other factors also induce temporary effects on the pressure and sink rate. A pocket of gas trapped in a hydraulic system will tend to dissolve into the oil upon pressurization. This action may not be instantaneous, and as the gas pocket dissolves, the pressure will tend to decrease. Occasionally, the seals and packing in valves may yield under the stress of pressurization. This deflection also may not be instantaneous and can result in an abnormal sink rate.

Only after the effects of these influences have subsided, and provided that no significant leaks are present in the system, as would be indicated by an abnormally high sink rate at the end of the thermal stabilization period, can reliable pressure measurements be made.

Accuracy and Traceability

The validity of a measurement made using a deadweight gauge, or any other device, is influenced by numerous factors other than basic performance parameters such as linearity, repeatability and hysteresis, to list a few. Typically, the largest contribution to the estimate of total uncertainty (the bounds within which the true value lies, often referred to as accuracy) is the uncertainty assigned to the standard or system used to provide traceability.

As comparative measurements are performed at each level in a measurement chain used to transfer the knowledge about a reference device to a test device, the potential for error increases. These additional errors generally, but not exclusively, are the result of performances parameters such as those stated above.

Significant additional contributions may be the result of environmental factors, operator intervention and human error. These are the most difficult to assess and eliminate, yet may contribute the greatest errors. To take full advantage of the performance characteristics of precision deadweight gauges (which require substantial operator manipulation and mathematical computation), appropriate precautions must be taken to minimize the risk of gross errors and to reduce the miscellaneous influences.

Deadweight Gauge Masses

The components of a deadweight gauge mass set are calibrated to provide knowledge of individual mass values, as well as an estimate of the contribution to the total uncertainty in the pressure measured with the instrument. Preservation of the condition of the masses is crucial to long term stability and reliability. Proper handling, such as careful and deliberate loading and unloading, removal of incidental contamination such as fingerprints and deadweight gauge oil, and proper storage of the masses will prolong the reliability of the calibration values. The recalibration schedule for a well preserved mass set is typically about 3 or 4 years. Heavily used, or less well preserved sets will likely require more frequent calibrations.

Calibration of deadweight gauge masses is typically performed through direct comparison of individual masses with standards of known mass measured on a precision balance or mass comparator. The calibration report for a mass set used with a high accuracy deadweight gauge will typically include individual mass and density values, as well as uncertainty and traceability information. Masses used with lower accuracy deadweight gauges may not list individual mass values, only nominal values of mass or pressure and a tolerance to which they were measured or adjusted. In either case, the calibration documentation is an important part of the mass set and should be preserved with the same care as the individual masses.

Deadweight Gauge Piston

As with the mass set, preservation of the high precision operating surfaces of the piston/cylinder assembly will prolong the reliability and long term stability of the deadweight gauge piston. Always handle the piston/cylinder assembly in accordance with the instructions provided in the operating manual. Proper handling of these assemblies will typically result in a recalibration schedule of about 3 or 4 years.

Calibration of a deadweight gauge piston/cylinder assembly is typically performed through direct intercomparison with a standard piston/cylinder having known effective area coefficients. The calibration report for a piston/cylinder assembly will typically include an effective area at zero pressure, pressure and temperature coefficients, mass, density, and surface tension values for the tare components, uncertainty estimates and other traceability information.

The piston calibration process is often referred to as the crossfloat. In a typical crossfloat, both the standard and test deadweight gauges are connected together and operated simultaneously. The difference in the pressures generated by the two gauges is reduced to a level beyond the performance of the measurements process. The degree to which the pressures are matched, and the random uncertainty of the measurement process contributes to the total uncertainty, is limited by the performance of the system, which is only as good as the worst component or aspect of the system. To obtain a level of performance in the crossfloat system that is better than a few parts in one hundred thousand, not only must both piston/cylinder assemblies be of sufficiently high quality, but some means of amplification of pressure or float position will also be necessary. Several methods of crossfloating using such electronic aids exist that enable adjustment of the loads, and matching of the pressure to less than one part per million.

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Chapter 3
Technical Description

Instrument Overview

The RUSKA 2485 deadweight gauge is a fully integrated, high precision, high accuracy piston pressure gauge system used as a standard to calibrate pressure transducers and bourdon tube gauges and as a precise pressure balance to accurately measure, maintain and control pressures up to 20,000 psi (1400 bar) in the low pressure version (RUSKA 2485-930), 40,000 psi (2800 bar) in the medium pressure version (RUSKA 2485-935), and up to 72,500 psi (5000 bar) in the high pressure version (RUSKA 2485-950). The RUSKA 2485 incorporates all the necessary components for accurate generation of any pressure within the range of the instrument. The features and functions of the system components are described below.

Instrument Features and Functions

The instrument features listed in Table 3-2 can be found in the figures listed by each feature. Refer to the sequence number shown in Table 3-2 to locate the feature in the appropriate figure. Refer to Table 3-1 for a functional description of each feature.

Table 3-1. Instrument Platform Functional Description

Sequence #	Functional Description
001	Instrument Cover The instrument cover can be removed to access the internal hardware for maintenance or repair. The left and right cover panels are secured by thumb-screws at the edges of the panels on the front, top and rear of the instrument.
002	Mass Loading Table Assembly The mass loading table assembly secures the piston/cylinder assembly in the main pressure housing and transmits the load of the mass set to the piston. A piston/cylinder assembly installed in the main pressure housing is protected from damage due to pressure release while under load, as well as when the load is removed with pressure applied, by thrust bearings inside the mass loading table assembly. Refer to Chapter 3, Mass Loading Table Assembly; and Chapter 3, Installation Kit, for further discussion of the mass loading table assembly.
003	Reservoir valve A Reservoir valve A is opened to recharge the hand pump and closed to provide a positive cutoff to the reservoir to allow pressurization of the instrument.

Sequence #	Functional Description
004	Pressure Valve B Pressure valve B serves two functions. In the low pressure version (RUSKA 2485-930), pressure valve B allows recharging of the hand pump while the system remains at pressure by isolating the pump and reservoir from the system. In the high pressure version (RUSKA 2485-950), which includes an integral pressure intensifier, pressure valve B is used as the reservoir cutoff valve for pressures up to 20,000 psi (1400 bar), and is opened when activating the intensifier to generate pressures up to 72,500 psi (5000 bar).
005	Intensifier Valve C The high pressure version (RUSKA 2485-950) includes an integral intensifier. After charging the system to approximately 20,000 psi (1400 bar), intensifier valve C is closed to activate the intensifier for pressure generation up to 72,500 psi (5000 bar).
006	Intensifier Valve D System valve D, on the high pressure version (RUSKA 2485-950), serves two functions. The primary function of system valve D is to allow recharging of the integral intensifier without removing the pressure from the system. A secondary function of system valve D is fine adjustment of the float position of the high pressure pistons when the friction of the seals in the intensifier do not allow such fine control.
007	Pump Position Indicator The RUSKA 2485 incorporates a hand operated positive displacement screw type pump for generating hydraulic pressure. The position of the hand pump plunger, and the amount of remaining stroke, is indicated by the relative position of the pump position indicator located in the opening in the top of the instrument cover.
008	Pump Handles The instrument is supplied with four pump handles for optimum control of the pump. The handles can be secured to the pump spindle nut by gentle tightening using a wrench on the milled flats near the spindle nut end of each handle.
009	Pump Spindle Cover The pump spindle cover prevents contact with the spindle lubrication.
010	Pump Lubrication Port Cover The pump lubrication port cover prevents contamination from entering the pump lubrication port.
011	Air Bleed Screw Cover (RUSKA 2485-930 & RUSKA 2485-950) The air bleed screw cover prevents contamination from entering the instrument through the air bleed screw access port in the top of the instrument cover.
012	Safety Head And Rupture Disk Assembly To prevent over-pressure of the hand pump assembly, a safety head and rupture disk assembly is installed into a special port in the side of the pump housing. Should the pump pressure exceed the rupture disk rating, the pressure will be vented to the internal reservoir, thereby preventing damage to the instrument or the operator. A replacement rupture disk must be installed prior to further operation. Refer to Chapter 5 for specific instruments on replacing the rupture disk.

Sequence #	Functional Description
013	Pressure Monitor (Dial Gauge) The pressure monitor provides a direct reading of the pressure applied to the hand pump. In the high pressure version (RUSKA 2485-950), when the integral intensifier is activated, the pressure monitor also indicates approximately 1/5th of the system pressure.
014	Internal Reservoir Cover The instrument is provided with a 250cc capacity internal reservoir. The internal reservoir cover prevents contamination of the fluid in the reservoir.
015	External Reservoir Port (RUSKA 2485-950 Only) Should the internal reservoir have insufficient capacity for high volumes of work, a port is provided on the rear of the instrument for attaching an external, high capacity reservoir, such as the RUSKA 2419-800, 1500cc reservoir and a high flow transfer pump (Model 5202). When an external reservoir is not connected, the external reservoir port becomes a convenient location to attach a manometer for establishing a precise measure of zero pressure.
016	Reservoir Source Valve (RUSKA 2485-950 Only) The reservoir source valve is used to select between the internal reservoir and an external reservoir or manometer.
017	Reservoir Relief Valve (RUSKA 2485-950 Only) The internal reservoir plumbing is protected from inadvertent over-pressure through the use of a relief valve set to approximately 100 psi.
018	Test Port Manifold And Adapters In addition to the test port at the base of the main pressure housing, a test port manifold is supplied with an assortment of adapters. The test port manifold, with the appropriate adapter installed, is designed to be mounted to the auxiliary pressure housing without the use of tools. The design of the test port manifold allows simple and quick installation of the manifold, while promoting durability of the seal.

⚠ Caution

Due to the thread configuration of some of the adapters, they may not be rated to the full pressure of the instrument. Refer to Figure 4-2 for appropriate pressure rating of each adapter.

Sequence #	Functional Description
019	Test Port Manifold Retaining Nut The test port manifold retaining nut secures the test port manifold to the auxiliary pressure housing to provide a positive seal at full instrument pressure. Securing the test port manifold to the auxiliary pressure housing with the retaining nut requires no tools.

Sequence #	Functional Description
020	Oil Drain Line During operation of the instrument, oil passes between the precision surfaces of the piston and cylinder assembly. This oil drains down the main pressure housing and lubricates the drive sleeve bearings. As the oil flows out of the drive sleeve, it drains through a hole in the instrument base. Beneath the base, the oil is collected in a clear plastic tube. This tube is equipped with a barbed connection. An additional length of tubing is found in the setup kit. Mate the tubing found in the set up kit with the barbed connection on the oil drain line. This will allow the waste hydraulic oil to be piped to an acceptable refuse container. Please dispose of the waste oil properly. NEVER REUSE waste hydraulic oil.
021	Fill Pump Assembly (RUSKA 2485-930 & RUSKA 2485-935) The fill pump is a motorized pump which facilitates the bleeding of external lines or device under test. The pump is powered from the drive motor assembly. A power pigtail extends from the bottom of the drive motor housing and plugs into a power inlet receptacle on the back side of the pump assembly.
022	Fixed Support Leg The instrument platform is supported by three legs. One of these legs is fixed and is not adjustable. This fixed support leg is positioned directly below the main pressure housing to prevent deflection of the instrument base when the load is applied. This lack of deflection in the instrument base provides more stable adjustment of the instrument level.
023	Auxiliary Support Leg Should the operator attempt to move the instrument while a mass load is applied, the auxiliary support leg will prevent the instrument from tipping over.
024	Adjustable Support Legs The model RUSKA 2485 incorporates two adjustable support legs positioned at the front and rear of the right side. Adjustment of these legs may be required upon installation of the instrument, and according to the level vial attached to the instrument base, each time a significant change is made to the mass load.
025	Level Vial A sensitive "bulls eye" level vial is mounted at the front of the instrument platform to provide easy measurement of the "level" of the instrument. When the axis of rotation of the piston/cylinder assembly is significantly off of vertical, the bubble in the level vial will be conspicuously out-of-center.
026	Drive Motor Assembly The principal use of the drive motor is to maintain consistent relative motion between the piston and cylinder when the inertia of a small mass load is insufficient to maintain adequate free-rotation time. The drive motor assembly also supplies power to the fill pump assembly (RUSKA 2485-930 & RUSKA 2485-935 Only).
027	Power Receptacle And Fuse Holder Power to the optional drive motor assembly is switchable between 115 or 230 VAC, and 50 or 60 Hz. The power RECEPTACLE on the rear of the drive motor assembly contains the necessary fuses to prevent electrical overload of the motor.

Sequence #	Functional Description
028	Drive Motor /Fill Pump Power Switch The drive motor assembly is equipped with a power switch on the left end. This power switch controls the drive (rotation) motor and, on the RUSKA 2485-930 and RUSKA 2485-935, the switch also controls the motorized fill pump.
029	Drive Motor Power Lamp The drive motor assembly includes an indicator lamp to show the state of the electrical motor. The lamp is located on the left side of the drive motor assembly next to the power switch.
030	Drive Belt The rotary action of the drive motor is transferred to the drive sleeve through an elastomeric drive belt installed on the pulleys mounted on the drive motor and the drive sleeve.
031	Drive Sleeve A thin line machined around the periphery of the drive sleeve approximately 3/16 of an inch (5 mm) above the drive belt pulley is used as a reference for measuring the proper float position of the piston/cylinder assembly. Pressure is applied to the piston/cylinder assembly until the piston and mass load are floating at a position where the bottom edge of the hanger mass (designation 01) coincides with the line on the drive sleeve. The drive sleeve provides the rotary motion for the mass loading table through contact with a roller pin mounted in the top of the drive sleeve. The drive sleeve also provides a boundary between the mass load and the oil draining down the side of the main pressure housing.
032	Roller Pin The roller pin mounted in the top of the drive sleeve provides rotation of the mass loading table assembly through contact with a drive pin in the bottom of the mass loading table. The roller pin can be removed by simply grasping the pin and lifting. It is recommended that the roller pin be removed when not required, and that motor driven rotation be used only when a small load or other special test requires its use.
033	Float Position Mirror Block A small mirror mounted to the float position mirror block at a 45 degree angle provides easy visual observation of the float position of the hanger mass relative to the line on the drive sleeve.
034	Float Position Sensor Assembly An optional electronic float position sensor assembly is available under part number 2485-913. The electronic sensor allows more precise and simpler measurement of the float position through the use of the RUSKA 2456 piston gauge monitor or other device.
035	Optional Thermometer Assembly A liquid in glass thermometer, with protective metal sleeve and mounting hardware is available as an Option (P/N 2485-202-913). Temperature measurement is required to minimize the thermal effects when operating the RUSKA 2485 Piston Pressure Gauge. An electronic thermometer (PRT) is also available as an option.

Sequence #	Functional Description
036	Mass Set Each individual piece in the mass set is completely machined from non-magnetic 300 series stainless steel, in kilogram denominations to provide easy, direct comparison to mass standards in the meter-kilogram-second system of measure. The final mass is adjusted to within 15 parts per million of the nominal denomination in units of apparent mass versus brass standards (density reference 8.4 g/cm^3). The adjustment is performed in such a way as to maintain a balance about the centerline by milling a symmetrical pattern of holes on the bottom surface of the mass concentric with the axis. The mass set includes a hanger mass for maintaining a low center of gravity while supporting the full load, nineteen 5 kilogram platters, and incremental denominations in a 5-3-2-1 sequence down through 200 grams. Each mass in the set is marked with the nominal mass denomination, a sequence number and the serial number of the set for traceability. When supplemented with a laboratory style mass set, typically including 10 mg through 100 g masses, the load can be trimmed to generate any pressure within the range and sensitivity of each piston/cylinder assembly. The mass set is supplied in 5 storage cases. The storage case for the hanger mass and incremental platters also accommodates three piston/cylinder assemblies. Refer to Figures 3-7 and 3-8.

Mass Loading Table Assembly

The mass load on the RUSKA 2485 is transmitted to the piston through a conical arrangement in the mass loading table assembly that locates on the spherical end of the piston. This locating method, which allows any minute imbalance in the load to be self-aligning and self-balancing, promotes a higher level of performance than with a rigidly mounted load, which can result in bent, broken or worn piston/cylinder components. The piston/cylinder protection provided by the precision fit of the components in the RUSKA 2485 mass loading table assembly eliminates the necessity for a secondary piston and guide bushing, which could result in increased friction and reduced performance.

Installation Kit

The installation kit (part number 2485-202 or 2485-203) contains all the necessary hardware, such as wrenches, seals and piston/cylinder cleaning tools, for operating of the RUSKA 2485 deadweight gauge. See Appendix B for detail of the setup kit.

RUSKA 2485 Piston/Cylinder Assemblies

The piston/cylinder assemblies used in the RUSKA 2485 are manufactured from high grade tungsten carbide. The precision surfaces of each piston/cylinder assembly are finish lapped and matched to provide optimum performance with minimal leakage over a wide pressure range. The high level of performance achieved with the RUSKA 2485 piston/cylinder assemblies is such that only three ranges are required to cover the total pressure range of the instrument while maintaining optimum accuracy. Various intermediate ranges are available, however, to suit specific applications.

The effective area of each piston/cylinder assembly is adjusted such that, for a given load in kilogram denominations, it will generate nominal pressure increments in either English units (psi) or S.I. units (bar). All assemblies are permanently identified with a pressure unit/increment designator and a unique serial number for traceability. An example of the pressure unit/increment designator for one of the English piston/cylinder assemblies is P200. The "P" designates the unit of measure psi, and "200" indicates the nominal increment. For each kilogram loaded on the piston, the nominal pressure increment will be 200 psi. For a piston/cylinder assembly with a B0.5 pressure unit/increment designator (S.I. units), each kilogram would generate 0.5 bar. A B50 piston/cylinder will generate 50 bar per kilogram, or 5000 bar (72,500 psi) for the full mass load of 100 kilograms.

The RUSKA 2485 cylinders are simple in configuration and there are no mounting flanges or other geometric irregularities that can result in complicated stresses in the cylinder. Further, the cylinder is restrained in the pressure housing in such a way as to minimize stress due to mounting and sealing. The mounting arrangement for the piston/cylinder assemblies in the pressure housing also allows quick and easy change-out of all ranges while providing a maximum level of protection to the precision measuring components.

High Pressure Piston/Cylinder Assemblies

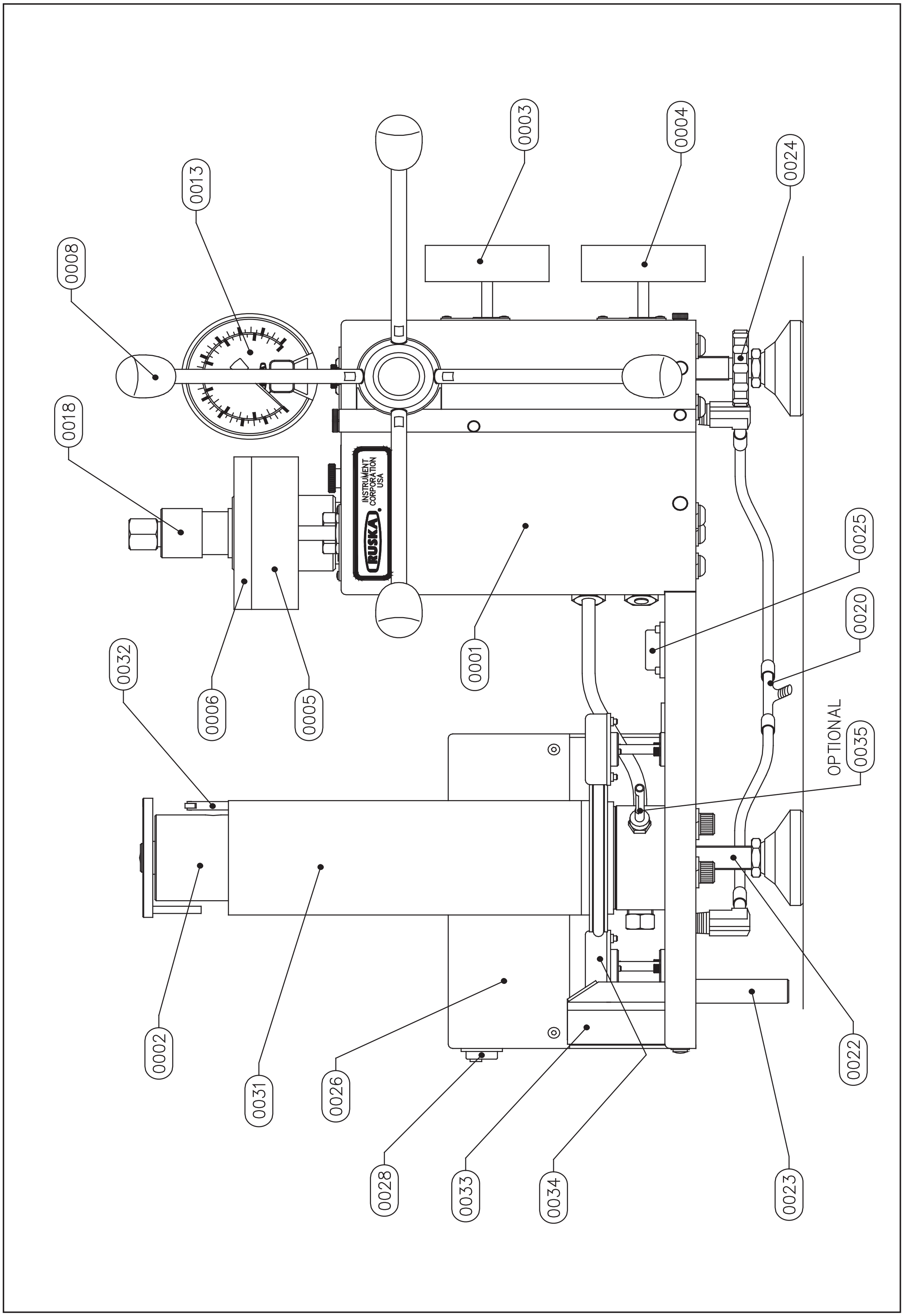
Due to the extreme stress at pressures up to 72,500 psi (5000 bar), the high pressure piston/cylinder assemblies have a slightly different geometry than the lower pressure assemblies. The high pressure piston/cylinder assemblies retain the non-complex configuration with the seal at the bottom of the cylinder. The piston and cylinder are, however, significantly smaller.

To assure proper alignment of the high pressure assemblies and to ensure positive sealing at the base of the cylinder, a special cylinder "keeper" is installed in the pressure housing prior to installation of the piston/cylinder assembly. The seal configuration of the keeper allows the use of a standard elastomeric O-ring seal at the base of the cylinder while providing positive sealing up to 72,500 psi (5000 bar). The design of the keeper sealing surfaces enhances the durability and allows extended use of the seals. The lower seal on the keeper is the same configuration as the seal used on the test port manifold.

Table 3-2. Instrument Platform Features

Sequence Number	Figure Number(s)	Feature
001	3-1 thru 3-4	Instrument Cover
002	3-1 thru 3-4, 4-3	Mass Loading Table Assembly
003	3-1 thru 3-4	Reservoir Valve A
004	3-1 thru 3-4	Pressure Valve B
005	3-1, 3-3, 3-4	Intensifier Valve C
006	3-1, 3-3, 3-4	System Valve D
007	3-4	Pump Position Indicator
008	3-1 thru 3-4	Pump Handle (4 each)
009	3-3, 3-4	Pump Spindle Cover
010	3-4	Pump Lubrication Port Cover
011	3-4	Air Bleed Screw Cover
012	3-6, 5-1	Safety Head and Rupture Disk Assembly

Sequence Number	Figure Number(s)	Feature
013	3-1 thru 3-4	Pressure Monitor
014	3-4	Internal Reservoir Cover
015	3-2	External Reservoir Port
016	3-2 thru 3-4	Reservoir Source Valve
017	3-5, 3-6	Reservoir Relief Valve
018	3-1 thru 3-4, 4-2	Test Port Manifold and Adapters
019	3-2 thru 3-4, 4-2	Test Port Manifold Retaining Nut
020	3-1, 3-2	Main Oil Drain Cup
021	3-1, 3-2	Auxiliary Oil Drain Cup
022	3-1 thru 3-3	Fixed Support Leg
023	3-1, 3-2	Auxiliary Support Leg
024	3-1 thru 3-3	Adjustable Support Legs (2 each)
025	3-1, 3-2, 3-4	Level Vial
026	3-1, 3-2, 3-4	Drive Motor Assembly
027	3-2, 3-4, 4-1	Power Receptacle and Fuse Holder
028	3-1, 3-4	Drive Motor Power Switch
029	3-2, 3-4	Drive Motor Power Lamp
030	3-2, 3-4	Drive Belt
031	3-1, 3-2	Drive Sleeve
032	3-1 thru 3-3, 4-3	Roller Pin
033	3-1, 3-4	Float Position Mirror Block
034	3-1, 3-4	Float Position Sensor Assembly
035	3-1, 3-4	Thermometer Assembly (optional)
036	3-7, 3-8	Mass Set



gmd02.eps

Figure 3-1. Front View - RUSKA 2485-950 (similar to RUSKA 2485-930)

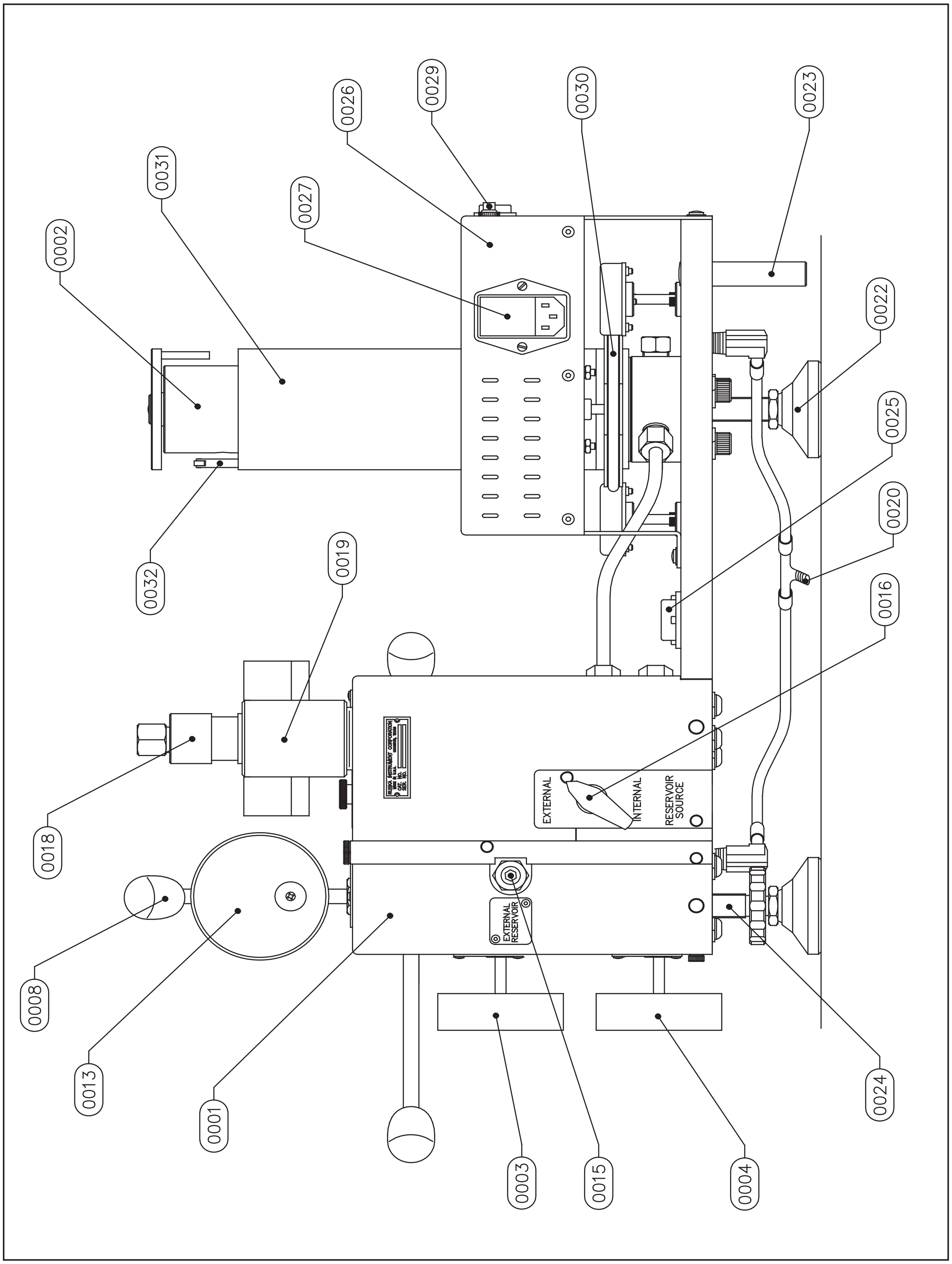


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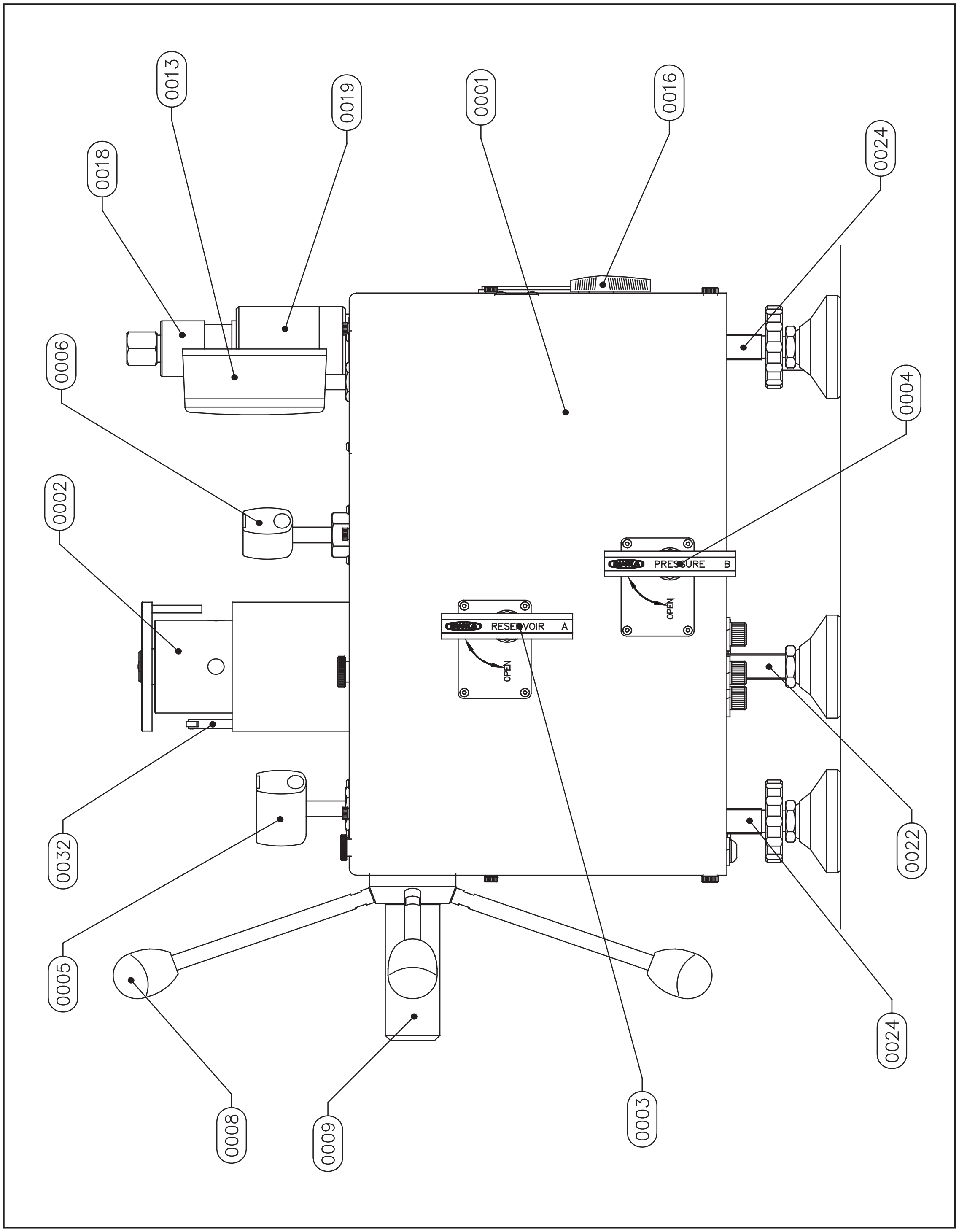
Figure 3-2. Rear View - RUSKA 2485-950 (similar to RUSKA 2485-930)



gmd04.eps

Figure 3-3. Right Side View - RUSKA 2485-950 (similar to RUSKA 2485-930)

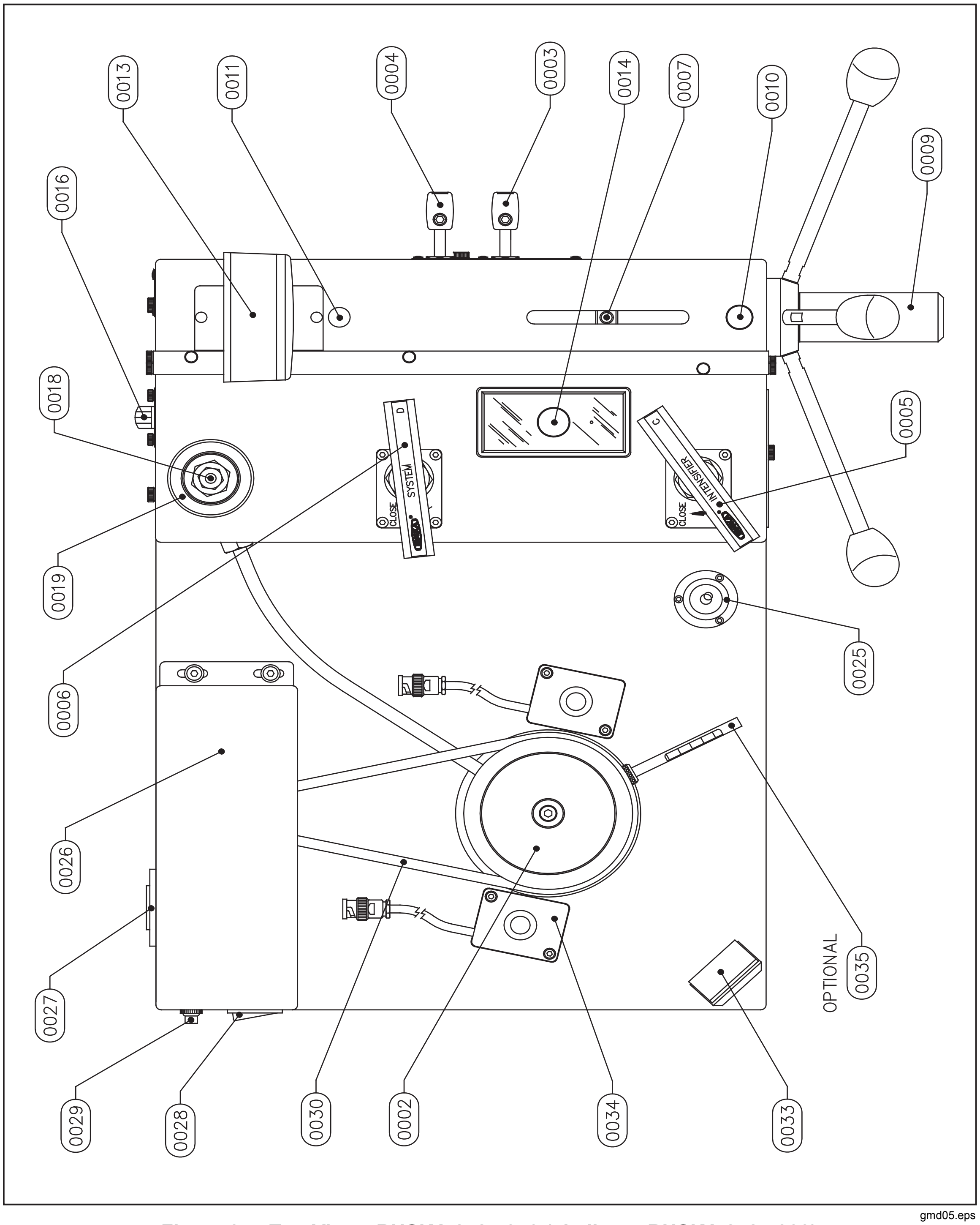
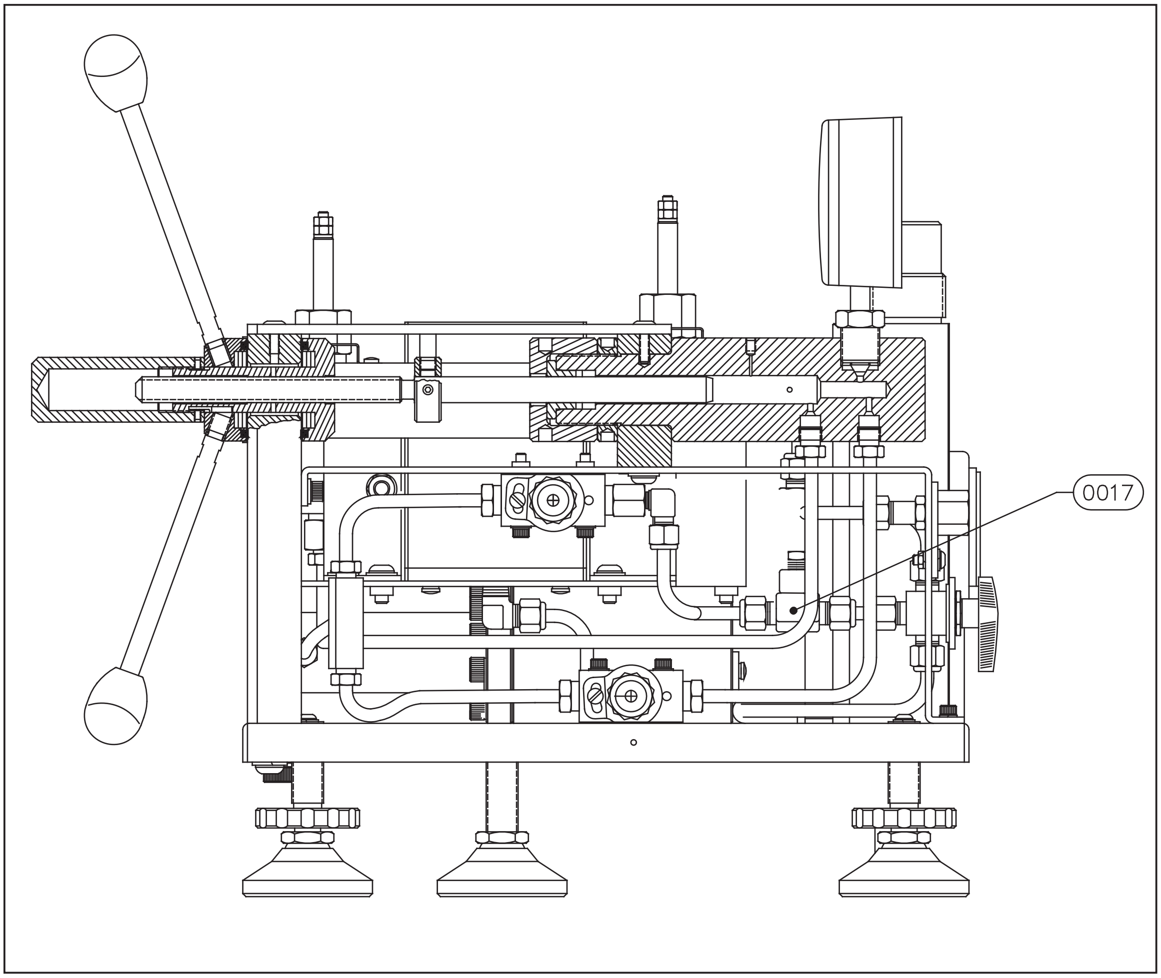


Figure 3-4. Top View - RUSKA 2485-950 (similar to RUSKA 2485-930)



gmd06.eps

Figure 3-5. Right Side View - RUSKA 2485-950 without Cover

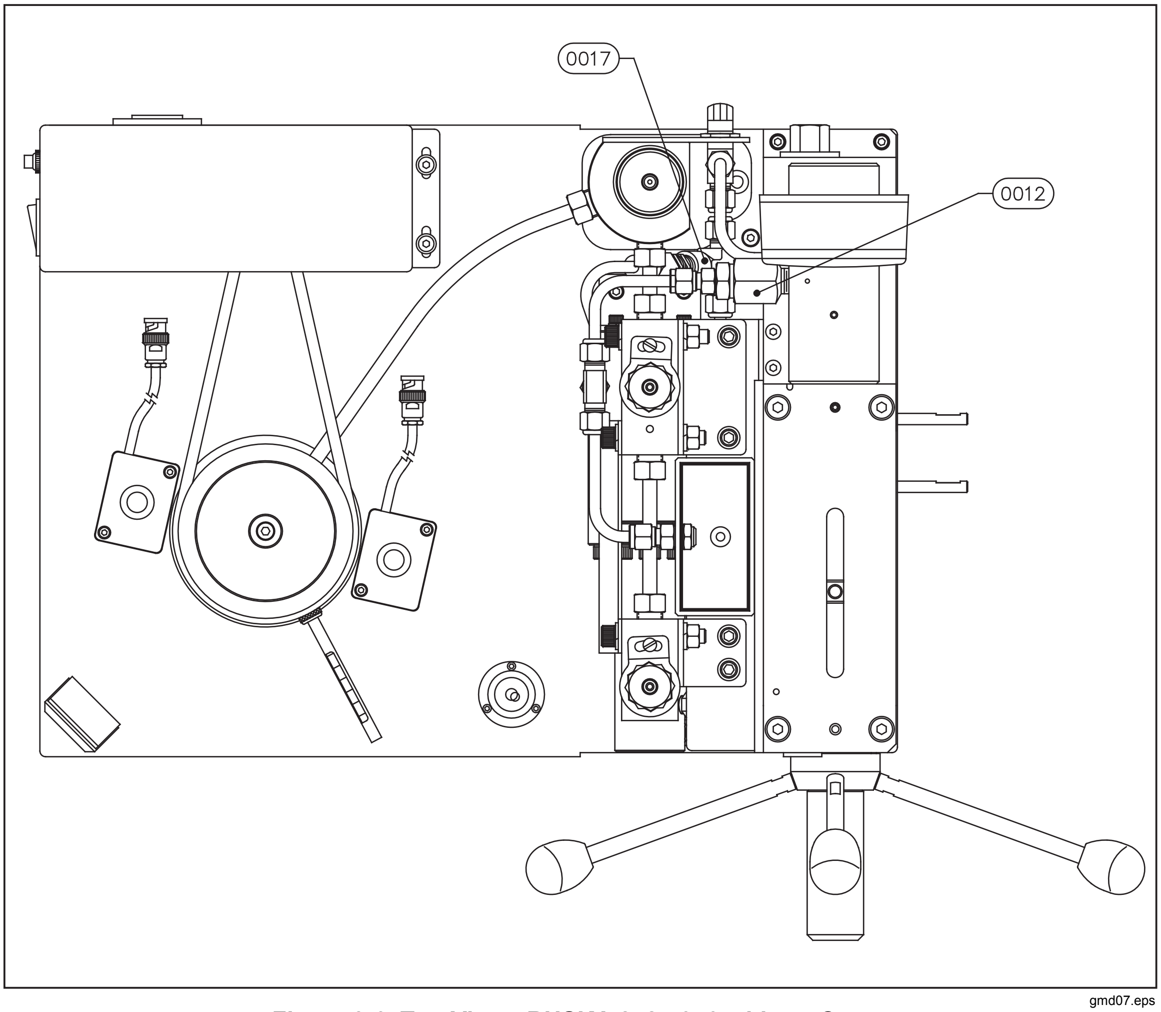


Figure 3-6. Top View - RUSKA 2485-950 without Cover

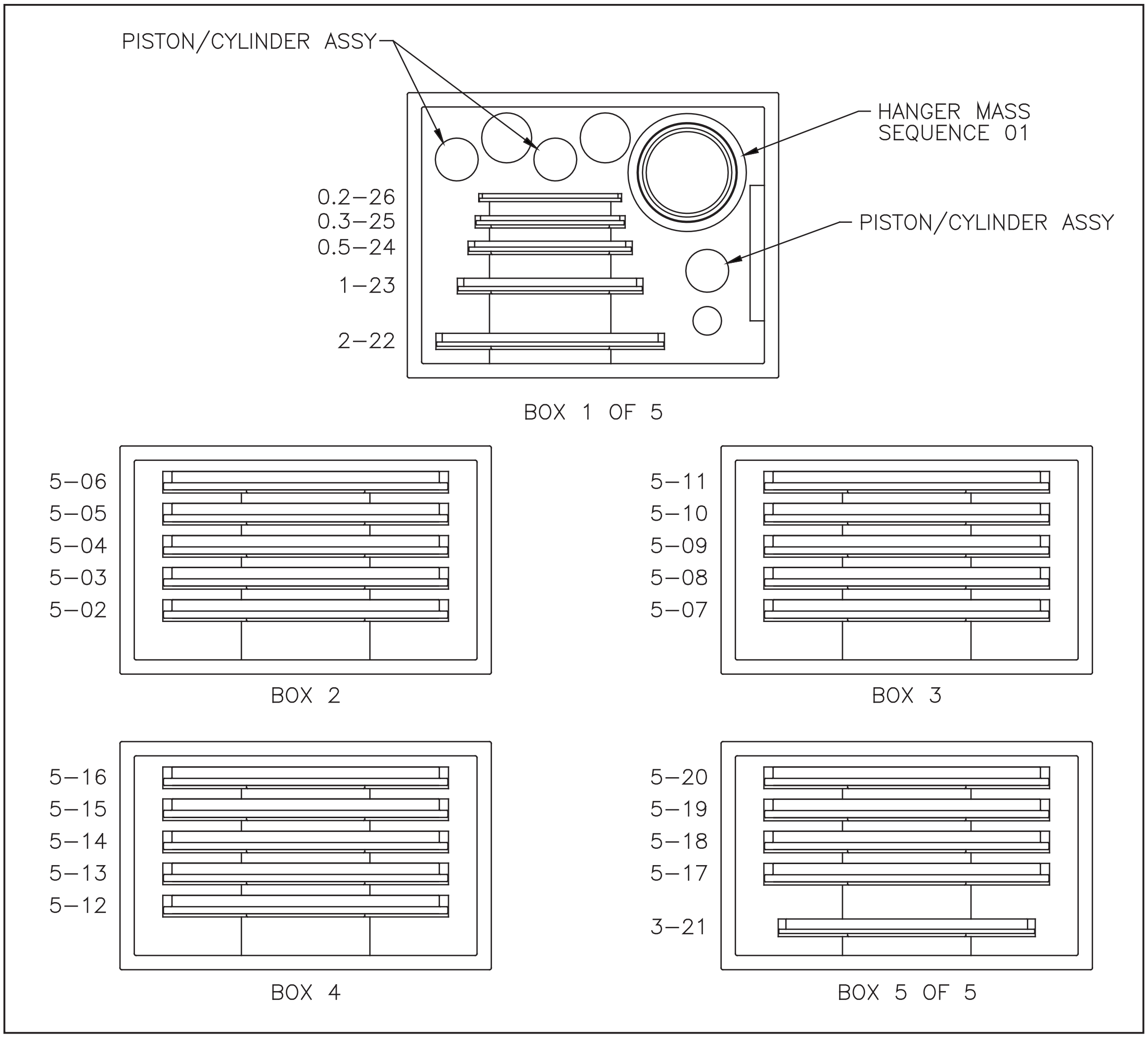


Figure 3-7. Mass Set in Boxes

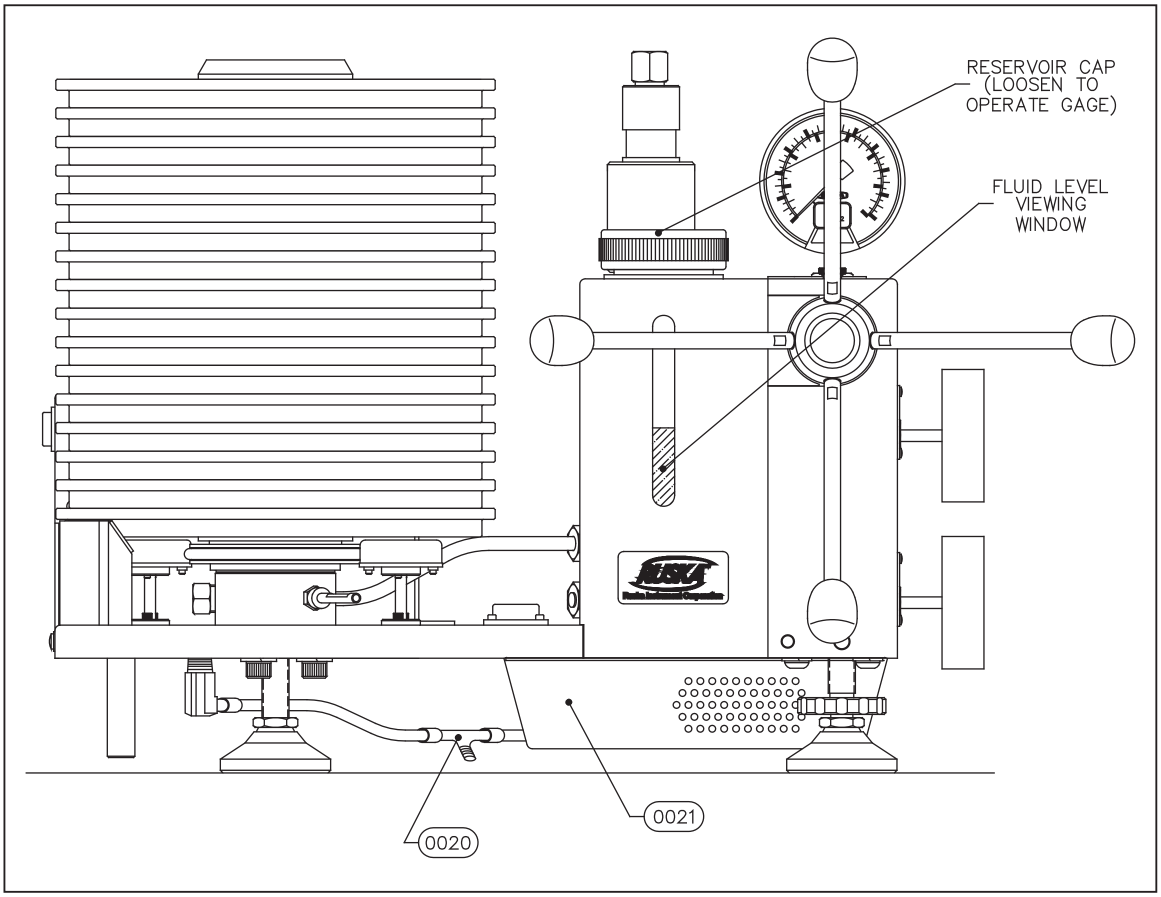


Figure 3-8. Instrument Platform (with Partial Mass Set Loaded) - RUSKA 2485-930 and RUSKA 2485-935

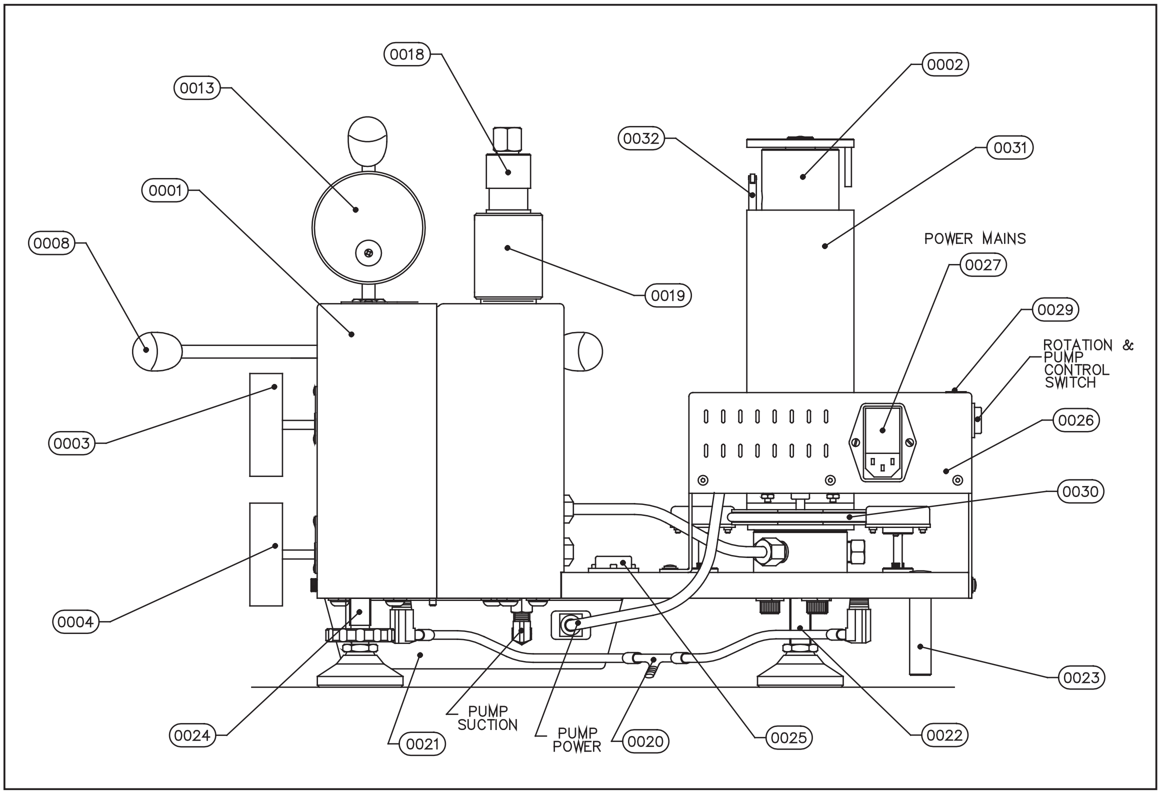


Figure 3-9. Rear View - RUSKA 2485-903 and RUSKA 2485-935

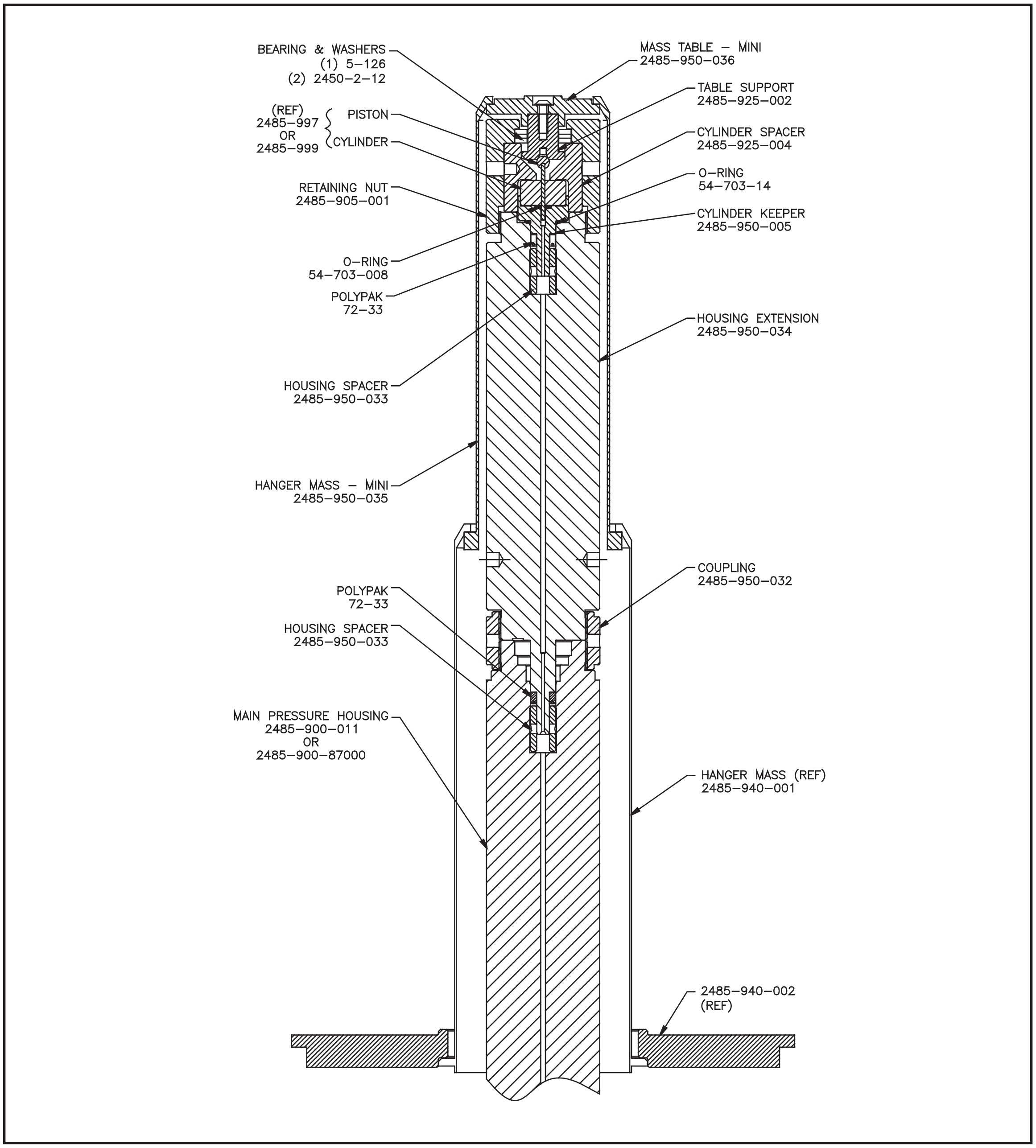
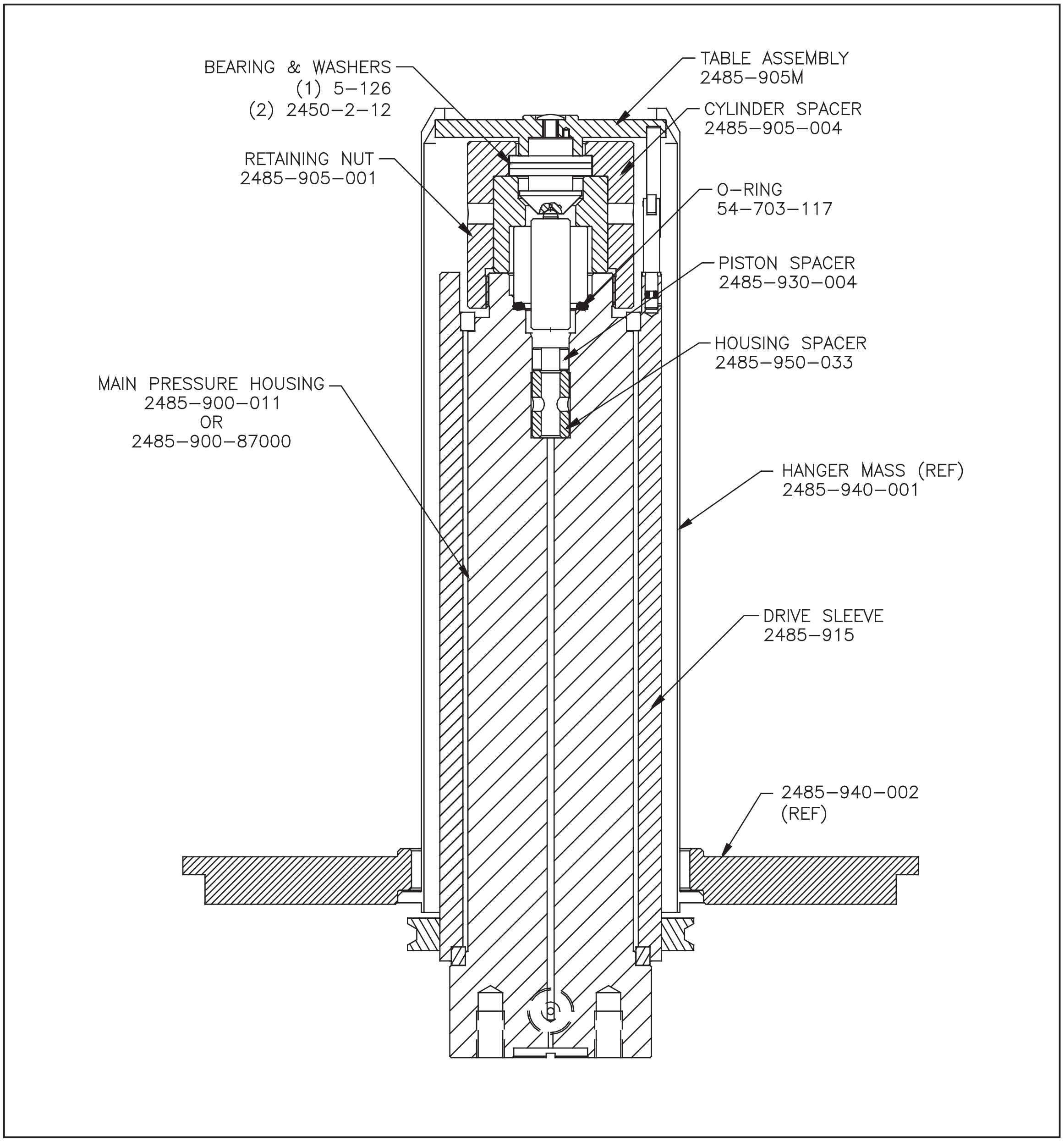


Figure 3-10. Section View of Pressure Column - Extended Range Column and Extended Range P/C - RUSKA 2485-950



gmd12.eps

Figure 3-11. Section View of Column Assembly - RUSKA 2485-930 or RUSKA 2485-950 with Low Range P/C

Chapter 4
RUSKA 2485 System Operation

Introduction

The RUSKA 2485 deadweight gauge is available in two configurations, a low pressure version (RUSKA 2485-930) rated to 20,000 psi (1400 bar), and a high pressure version (RUSKA 2485-950) rated to 72,500 psi (5000 bar). The high pressure version incorporates an integral intensifier for operation above the 20,000 psi (1400 bar). Operation of the intensifier requires the use of additional valves and plumbing, and a slightly different valve operating procedure for generating pressures. The following sections describe the general operation of the instrument in terms generic to both high pressure and low pressure versions, as well as specific valve operating procedures for generating pressure with each version of the instrument

Precautions

⚠ Warning

Pressurizing vessels and associated equipment are potentially dangerous. The apparatus described in this manual should be operated only by personnel trained in procedures that will assure safety to themselves, to others, and to the equipment.

Safe and proper operation of this system requires that the operator have a thorough knowledge of the operation of the system and follows a strict procedure for pressurizing and depressurizing the system to prevent damage to the delicate internal components and to prevent injury to personnel. Operation of the hand pump and valves must be performed in such a way as to maintain control of the system at all times. At the conclusion of operation of the instrument, the pressure must be removed and the valves set to a position that will not trap pressure in any portion of the system. During operation of the system, a warning sign notifying personnel of the state of the system should be placed in close proximity to the system.

Versions of the instrument that include the drive motor option require a grounded 115 or 230 VAC power source. To prevent electrical shock when servicing an instrument with the drive motor option, the power switch must be set to the off position and the power cord disconnected from both the instrument and the power outlet.

The RUSKA 2485 is shipped from the factory in a special configuration. A small amount of pressure is trapped in the instrument to prevent air from contaminating the hydraulic system. The procedure to remove this pressure, described later in this section, must be followed to prevent damage to the delicate internal components and to prevent injury to personnel.

Installation and Preparation for Use

Selecting a Location

The RUSKA 2485 should be installed in a location where the temperature is maintained between 18 degrees and 28 degrees Celsius, and the relative humidity is between 20% and 75%. Temperature stability may be more important than the actual temperature. A change in the temperature of 1 degree per hour may be excessive for some pressure measurements. The installation location should be free from excessive personnel traffic and air drafts. Airborne dust is also undesirable, but clean-room standards are not required.

The workbench on which the instrument is to be installed must be sturdy enough to safely support up to 400 pounds (180 Kg) without significant deformation. Ample working space should be allowed where tools, worksheets or other technical data can easily be manipulated.

If the instrument includes the drive motor option or electronic float position/temperature option, a suitable power source is required at the installation location. The power source must be either 115 VAC or 230 VAC and 50 or 60 Hz, and must be rated to at least 15 watts.

Setting Up the Instrument Platform

Remove the instrument platform from its shipping box and place it on the workbench. Make sure that the circular foot plates are located flat against the workbench surface and that no foreign material is trapped between the foot plates and the workbench. Remove any packing materials from the instrument platform and main pressure housing and from inside the internal reservoir. Inspect the instrument platform for shipping damage.

Move the instrument platform to the proper position on the workbench, keeping in mind that the final position may be influenced by any pressure connecting lines required to accommodate other equipment. Level the instrument platform, according to the bulls-eye level vial, by rotating the two adjustable support legs located at the front and rear of the right side of the instrument platform.

The voltage selector switch position must be verified prior to applying power. As shown in Figure 4-3, the selected voltage is displayed through a small window in the power cord receptacle on the rear of the drive motor assembly. If the incorrect voltage is displayed, the voltage selector switch position and the fuses must be changed.

To change the voltage selector switch position and fuses, open the voltage selector/fuse holder compartment on the power receptacle using a flat blade screwdriver in the slot directly above the voltage display window. Remove the voltage selector wheel, rotate to the proper setting and reinstall.

⚠ Caution

Do not rotate the selector wheel while it is installed.

Slide out both fuse holder trays and verify that the proper fuses are installed. Close the voltage selector/fuse holder cover and verify that the proper voltage is displayed.

A power pigtail with a female plug (Style IEC 60320) emerges from the lower surface of the drive motor assembly. This pigtail supplies power to the fill pump assembly mounted below the base. See Figure 3-9. This pigtail may have come loose during shipping. Verify that this pigtail is securely inserted into the male socket (power inlet) on the fill pump sub-assembly. Read the sections regarding fill pump operation before energizing the fill pump.

Ensure that the drive belt is properly positioned in the pulleys on the drive motor and the drive sleeve. Connect the power cord supplied with the instrument to the power cord receptacle on the drive motor assembly and then to the power outlet at the installation location. Depress the "1" on the power switch and verify that the drive sleeve rotates in the clockwise direction. Depress the "0" to switch the power off.

A thermo well is located in the front right quadrant of the base of the main pressure housing. This well allows for the temperature measurement of the column and Piston/Cylinder. This well will accept a liquid-in-glass thermometer or an electronic temperature probe (PRT). An optional thermometer assembly is available from Fluke under the part number 2485-202-913. If an electronic temperature measurement is desired, the RUSKA 2456 Piston Gauge Monitor may be the optimal choice. The RUSKA 2456 piston gauge monitor will make an electronic temperature measurement as well as measuring the float position of the mass platters. Contact your Fluke Sales representative for more information on the RUSKA 2465 PGM.

Tighten the fitting into the housing about 1/4 turn past finger tight. If a thermometer is used, position the thermometer so the graduations show through the slot in the thermometer support tube, and rotate the support tube so that the temperature can be measured with the masses installed. It may be beneficial to apply heat sink compound into the temperature will prior to installing the temperature probe.

Fill Pump Assembly — RUSKA 2485-930

The fill pump is a motorized pump which facilitates the bleeding of external lines or device under test. Before using the fill pump, check the reservoir level to assure an ample amount of fluid is available. Next, loosen the reservoir lid to allow air into the reservoir. The reservoir valve and the system valve must be open. Energize the pump by toggling the control switch on the left hand side of the drive motor assembly. Open a line or bleed a fitting at the high point of the circuit to allow the escape of trapped air.

Operating the fill pump with the system and reservoir valves closed should do no harm to the system; however, operating the pump for more than 2-3 minutes with the valves closed will warm the hydraulic oil above ambient temperature and is therefore not recommended.

The pump may be damaged if the reservoir is allowed to run dry.

Preparation for Use

The RUSKA 2485 is shipped from the factory with a small amount of pressure trapped in the system. After completing the installation according to Chapter 4, Setting Up the Instrument Platform, follow the step-by-step procedure described below to safely remove the pressure from the instrument and prepare the instrument for use.

1. Rotate the Reservoir Source Valve on the rear of the instrument to the internal reservoir position.
2. Thread the four pump handles carefully into the hand pump spindle nut on the front of the instrument.

⚠ Caution

Do not rotate the hand pump spindle during installation of the handles.

3. Carefully tighten the hand pump handles using a wrench on the flats near the pump spindle end of each handle.
4. Slowly rotate the hand pump spindle counter-clockwise until the pressure displayed on the pressure mounted on the top of the instrument indicates between zero and about 500 psi (35 bar).

⚠ Caution

Be very careful not to go below zero as air will be pulled into the hydraulic system.

5. Carefully open Reservoir Valve A on the right side of the instrument.
6. Slowly rotate the hand pump spindle in the clockwise direction while monitoring the oil level in the internal reservoir. As the oil level rises above the fitting in the bottom of the reservoir, continue to rotate the hand pump in the clockwise direction while looking for gas bubbles in the oil. Continue rotating the hand pump until no gas bubbles emerge from the reservoir plumbing.
7. Add oil to the reservoir from a fresh, clean source until the oil level is near the fitting in the side of the reservoir.

⚠ Caution

Be certain that the oil added to the reservoir is the same type as that in the instrument.

8. Recharge the hand pump by rotating the pump spindle fully counter-clockwise, then clockwise one-quarter turn to remove any backlash in the spindle threads.
9. Close Reservoir Valve A.
10. Slowly rotate the hand pump spindle clockwise and observe the pressure monitor for an indication.

Note

Pressurization of the instrument to more than about 500 psi (35 bar) is unnecessary at this point. If more than one-quarter turn is required to obtain a pressure reading, some amount of air is likely trapped in the hydraulic system and should be removed prior to continuing. Instructions for removal of air from the system are included in Chapter 5, Maintenance and Troubleshooting.

If a pressure change is noted within about one-half rotation of the hand pump spindle, the time required to remove this air may be a greater inconvenience than operating the system in such a condition. A small amount of air trapped in the system will gradually dissipate and work its way out of the system during normal operation.

11. Repeat steps 4 and 5.
12. Verify that the hydraulic pressure has been removed from the system. When making connections to the pressure ports or test port manifold, or when installing a piston/cylinder assembly, Reservoir Valve A or Pressure Valve B, depending on the model version (low pressure RUSKA 2485-930, or high pressure RUSKA 2485-950), must be closed. Instructions for each of these operations and for general pressure generation, for each version of the RUSKA 2485, are described in the following sections.
13. Install the mirror block assembly (part number 2485-920) on the front left corner of the instrument platform as shown in Figures 3-1 and 3-4.

Mass Set

Although not essential, it is recommended that the masses be loaded and stored in sequence according to the sequence number marked on each piece. When placing the masses into the storage boxes, fill box 5 first, then 4 and 3, etc. Place the highest sequence number 5 kilogram mass at the rear of the box, moving toward the front with the lower numbered masses. The 3 kilogram mass is stored in the front of the box 5. The 2 kilogram through 0.2 kilogram masses, the hanger mass (sequence number 01) and the piston/cylinder assemblies are stored in box 1.

Test Port Manifold Connections

⚠ Caution

All pressure must be removed from the system prior to disconnecting the test port manifold from the auxiliary pressure housing. The test port manifold should be disconnected from the auxiliary pressure housing before attaching a device or instrument to be tested.

Remove all pressure from the system and close the appropriate valve to isolate the reservoir. Refer to Chapter 4, Valve Operating Procedure for RUSKA 2485-930; and Valve Operating Procedure for RUSKA 2485-950, for the specific valve operating sequence.

Loosen the test port manifold retaining nut until it is free of the threads on the auxiliary pressure housing. Turn the hand pump clockwise approximately 3 or 4 turns, then carefully lift the test port manifold off of the auxiliary pressure housing.

Inspect the seal on the lower end of the test port manifold. If the seal is excessively worn or leaks when pressurized, it should be replaced before continuing. To replace the seal, carefully rotate and slide the old seal off of the stem and discard. DO NOT USE ANY SHARP OBJECT TO REMOVE THE SEAL. Lubricate the new seal (part number 72-33) with a small amount of the deadweight gauge oil and carefully slide it onto the manifold stem. The flared end of the seal should be oriented toward the bottom of the manifold stem.

⚠ Caution

Any device or system connected to the test port manifold or other test port on the RUSKA 2485 must be clean and free of contamination to prevent the damage to the precision deadweight gauge components. If the deadweight gauge is to be used to calibrate devices that are not known to be clean, an external filter trap, such as 2436-800, can be used up to 40,000 psi (2800 bar). Use of a fine mesh filter to trap minute particulates can result in reduced sensitivity of the deadweight system. To obtain maximum sensitivity and the highest level of accuracy in a pressure measurement, the device under test must be clean.

Connect the device under test and any required adapters to the test port manifold (refer to Figure 4-4). Rotate the hand pump clockwise to adjust the oil level in the auxiliary pressure housing to within approximately 2 mm of the top. Guide the lower stem of the manifold into the auxiliary pressure housing. Open the appropriate valve to the reservoir and hand-tighten the test port manifold retaining nut. The test port manifold is now sealed and the device under test can be bled of air, if necessary, by pumping oil through the test port manifold and device under test.

Mass Loading Table Removal and Installation

⚠ Caution

All pressure must be removed from the system prior to disconnecting the mass loading table assembly from the main pressure housing.

Remove all pressure from the system and close the appropriate valve to isolate the reservoir. Refer to Chapter 4, Valve Operating Procedure for RUSKA 2485-930; and Valve Operating Procedure for RUSKA 2485-950, for the specific valve operating sequence.

Refer to Figures 4-4 and 4-5.

Loosen the mass loading table assembly retaining nut until it is free of the threads on the main pressure housing. Carefully lift the mass loading table assembly off of the main pressure housing.

At this point, the piston/cylinder assembly, or a shipping plug will be exposed and appropriate care should be taken to prevent damage or contamination. The exposed piston/cylinder assembly can be covered with a clean paper wiper to prevent contamination from airborne dust.

Clean any oil from the mass loading table components prior to reinstallation.

To install the mass loading table assembly onto the main pressure housing, carefully guide the mass loading table assembly retaining nut and cylinder spacer (inside the nut) over the piston/cylinder assembly (and cylinder keeper for the higher ranges), and tighten the retaining nut. As the o-ring and/or seal compress, some amount of feedback, in the form of resistance, will be felt by the operator. Continue to tighten the nut until the o-ring/seal compression is complete, as indicated by a sudden increase in resistance when the cylinder spacer inside the nut contacts the top of the main pressure housing. Secure the nut using the spanner wrench (part number 94-618) provided in the installation kit.

Piston/Cylinder Assemblies

Piston/Cylinder Assemblies

When a piston/cylinder assembly is not in use, it should be placed in the storage container to prevent contamination and damage to the precision finish surfaces. When a piston/cylinder is submitted for recalibration the mass loading table assembly should accompany the piston/cylinder assembly. The mass of each of these components, as well as the position of the reference plane (distance from the top loading surface of the weight loading table to the bottom of the piston) should be reevaluated periodically.

General

The heart of the RUSKA 2485 deadweight gauge is the piston/cylinder assembly. The precision fit of the pistons into the cylinders provides a very high level of sensitivity with very low sink rates. Several denominations are available to best match the deadweight gauge application. In some applications, more than one denomination may be required. The time required to change ranges in the RUSKA 2485 deadweight gauge is approximately 2 minutes.

Refer to Figure 4-5 and Chapter 1, Table 1-1, for a detailed view and descriptions of the various piston/cylinder configurations. Complete cleaning instructions for the various configurations are included in Chapter 5, Maintenance and Troubleshooting.

Selecting a Range

There are several factors to consider in the selection of the appropriate denomination piston/cylinder assembly for a particular application. In the order of general significance they are pressure range, nominal and minimum pressure increment, pressure resolution using a trim mass set, load resolution, accuracy at minimum pressure, and overall performance characteristics such as free-rotation time and float time or sink rate.

Most deadweight gauges experience a loss in performance at the extreme low end of the pressure range. This is usually apparent in the reduced amount of time that the load will remain spinning. This loss in performance is typically accounted for through a nominal increase, as a percentage of reading, in the uncertainty assigned to pressures generated below about 5 or 10 percent of the maximum pressure range, depending on the quality of the deadweight gauge.

Typically, the smaller the load on the piston, the shorter the rotation time and the more precise any trim adjustment must be. An example of this load resolution factor follows. The pressure generated by a piston operating at the full load of 100 kilograms would change one part per million (ppm) for a change in the load of 100 milligrams (mg). The change in the pressure generated by a higher range piston, with a total load of only 5 kilograms, however, would change 20 ppm for the same 100 mg trim adjustment.

A general guideline for selecting the appropriate piston/cylinder is to select the lowest range that covers the pressures in the particular application. If two ranges are required for a particular evaluation, use the lower range up to its maximum rating, and overlap one or two pressures using the higher range.

Piston/Cylinder Identification

All RUSKA 2485 piston/cylinder assemblies are permanently marked with the pressure unit/increment designator, the assembly serial number and the word "top" to ensure proper orientation when installed into the main pressure housing. The top of each piston is rounded to ensure alignment and proper operation of the mass loading table assembly. It is crucial that the piston and cylinder be installed in the proper orientation. Refer to Figure 3-11 and Figure 4-5 for a detailed view of the piston/cylinder markings and orientation.

When a RUSKA 2485 piston/cylinder assembly is not installed in the instrument, it should be stored in the shipping/storage container supplied with each assembly. The label on the container identifies the denomination and serial number of the piston/cylinder assembly. The container can be stored in the mass set storage box that contains the incremental platters and the hanger mass.

Piston/Cylinder Installation and Exchange — RUSKA 2485-930 and RUSKA 2485-950

⚠ Caution

All pressure must be removed from the system prior to installing or exchanging a piston/cylinder assembly in the main pressure housing.

⚠ Caution

Whenever handling the precision piston/cylinder components of the RUSKA 2485 deadweight gauge, use plastic or thin rubber gloves, or several thicknesses of low lint paper wipers, such as Kimberly-Clark Type 900 Kimwipes™ (part number 58-392) to prevent finger oils and salts from contacting the components.

Removing the Mass Loading Table Assembly

Remove all pressure from the system and close the appropriate valve to isolate the reservoir. Refer to Chapter 4, Valve Operating Procedure for RUSKA 2485-930/RUSKA 2485-935; and Valve Operating Procedure for RUSKA 2485-950, for the specific valve operating sequence. Remove the tare compensator disk and mass loading table assembly according to Chapter 4, Mass Loading Table Removal and Installation, and place them in an appropriate location.

Removing a Piston/Cylinder Assembly or Shipping Plug — RUSKA 2485-930 and RUSKA 2485-950

The procedure for removing a piston/cylinder assembly from the main pressure housing includes several critical steps. Read the entire procedure carefully before beginning. Complete Chapter 4, Removing a Piston Cylinder Assembly or Shipping Plug, before proceeding.

If a shipping plug is installed rather than a piston/cylinder assembly, remove it by simply grasping the top edge of the plug and rocking it gently side-to-side. Once the plug is free of the housing, place it in the appropriate storage location.

To remove a piston/cylinder assembly from the pressure housing, use an appropriate insulation between piston/cylinder components and fingers, and grasp the top edge of the cylinder with the left hand. Place the forefinger of the left hand directly above the piston.

Slowly rotate the hand pump spindle clockwise until the piston extends approximately 1/2 inch (1 cm) above the cylinder. Place the forefinger of the left hand on the top edge of the piston and apply a slight downward and lateral force to the piston. This will prevent the piston from exiting the top of the cylinder while turning the hand pump. It will also prevent the piston from exiting the bottom of the cylinder once the assembly is removed from the pressure housing.

Rotate the hand pump clockwise approximately 3 or 4 turns to free the cylinder from the pressure housing. Carefully lift the piston/cylinder assembly out of the pressure housing and place it in the appropriate storage container. Cover the piston/cylinder assembly, in the storage container, with clean oil and secure the storage container top. Wipe any excess oil from the storage container and place it in the appropriate storage location.

Installing a Piston/Cylinder or Shipping Plug — RUSKA 2485-930 and RUSKA 2485-950

Before installing a piston/cylinder assembly or shipping plug into the pressure housing, inspect the o-ring cylinder seal. If the o-ring is worn or leaks when pressurized, it should be replaced before continuing. Carefully locate the o-ring in the appropriate sealing groove.

Place a clean, low-lint wiper on the workbench. Carefully remove the top of the piston/cylinder storage container and set it aside. Using the appropriate insulation between piston/cylinder components and fingers, place the forefinger directly above the piston and empty any excess oil out of the storage container. Slide the piston/cylinder assembly out of the container and set it upright on the clean wipes.

Turn the hand pump spindle to adjust the oil level in the pressure housing to about the top of the o-ring cylinder seal. Firmly grasp the top edge of the cylinder with the left hand. Place the forefinger of the left hand on the top edge of the piston and apply a slight lateral force to the piston to prevent the piston from exiting the bottom of the cylinder when it is moved to the pressure housing.

Carefully insert the bottom of the piston/cylinder assembly into the pressure housing. Open the appropriate valve to activate the reservoir. While firmly holding the cylinder in place, press the piston down into the cylinder, then press the cylinder down firmly against the o-ring cylinder seal.

To install a shipping plug, rather than a piston/cylinder assembly, carefully insert the bottom of the shipping container into the pressure housing. Open the appropriate valve to activate the reservoir. Press the shipping container down firmly against the o-ring cylinder seal.

Installing the Mass Loading Table Assembly — RUSKA 2485-930 and RUSKA 2485-950

As described in Chapter 4, Mass Loading Table Removal and Installation, carefully guide the mass loading table assembly retaining nut and cylinder spacer (inside the nut) over the piston/cylinder assembly and tighten the retaining nut. As the o-ring and/or seal compress, some amount of feedback, in the form of resistance, will be felt by the operator. Continue to tighten the nut until the o-ring/seal compression is complete, as indicated by a sudden increase in resistance when the cylinder spacer inside the nut contacts the top of the main pressure housing. Secure the nut using the spanner wrench (part number 94-618) provided in setup kit part number 2485-202 or 2485-203.

Operating Procedure for the RUSKA 2485 Deadweight Gauge

This section describes the steps necessary to safely generate precise pressures with the RUSKA 2485 deadweight gauge. The steps described below are generic and are applicable to both versions of the instrument. Specific valve operating procedures, which are different for the two versions of the instrument, are detailed in Chapter 4, Valve Operation Procedure for RUSKA 2485-930, and Valve Operating Procedure for RUSKA 2485-950. Once the operator becomes familiar with the valving techniques for a particular version, the following steps should be followed to safely and efficiently generate the desired pressures.

Establishing Atmospheric Pressure

Verify that the instrument is at atmospheric pressure as indicated by the pressure monitor and that the reservoir is on-line by actuating the appropriate valves according to Chapter 4, Valve Operation Procedure for RUSKA 2485-930, and Valve Operating Procedure for RUSKA 2485-950.

When using the RUSKA 2485 deadweight gauge to calibrate a transducer or Bourdon tube gauge, zero pressure is often required for the initial and final observations. With the appropriate valves open to the reservoir (refer to Chapter 4, Valve Operation Procedure for RUSKA 2485-930/RUSKA 2485-935; and Valve Operating Procedure for RUSKA 2485-950), atmospheric pressure is allowed to act on the sensing element through the reservoir, which acts as a monometer.

If the reference plane of the instrument under evaluation is not at the same height as the fluid in the reservoir, there is a small pressure exerted on the instrument under evaluation. The magnitude of this pressure is equal to the difference in height between the reservoir level and the reference plane of the instrument under evaluation, multiplied by the density of the fluid (approximately 0.03 psi per inch or 0.08 bar per meter). For many high resolution and low pressure instruments, a manometer may be necessary to establish a precise zero for the instrument under evaluation.

Level the Instrument Platform

Adjust the level of the instrument, as necessary, each time the instrument is repositioned and each time a significant mass load change has been made. Rotate the adjustable support legs until the level vial indicates a level condition. Refer to Figures 3-1 through 3-4 to locate the adjustable support legs and the level vial.

Recharge the Hand Pump

Precision pressure measurements rely on the thermal stability of the pressure system. The action of changing pressure in the system induces significant thermal instability. To minimize the necessity for recharging the hand pump while at pressure, and therefore inducing further thermal instability, the hand pump should be fully recharged prior to initial pressurization of the system. Refer to Chapter 4, Valve Operation Procedure for RUSKA 2485-930/RUSKA 2485-935, and Valve Operating Procedure for RUSKA 2485-950, for the appropriate valving techniques for recharging the hand pump.

Load the Masses and Pressurize the System

The mass loading table assembly of the RUSKA 2485 deadweight gauge provides a high degree of protection for the piston/cylinder assemblies under normal use. However, the risk of damage or breakage is greatly increased with misuse and abuse. The following pressurization routine, Chapter 4, Install the Hanger Mass, through to Assess Stability, will minimize the risk of damage to the precision finish of the piston and cylinder assemblies.

⚠ Warning

Any SUDDEN shift, increase or decrease in the load on the piston can result in permanent damage to the piston. If, when loading and unloading the masses on the deadweight gauge, CAREFUL consideration is given to prevent damage to the precision finish of the masses, adequate protection will be provided for the piston.

Install the Hanger Mass

With ONLY the hanger mass (sequence 01) installed on the mass loading table, increase the pressure until the piston is floating.

Note

The approximate, or nominal, pressure generated using the RUSKA 2485 deadweight gauge can be computed from the pressure unit/increment designator marked on the tare compensator disk and the nominal mass designation marked on the masses.

Load Other Masses

1. Carefully load the next required mass onto the hanger mass. When loading the masses onto the deadweight gauge verify that they are in the proper sequence and align the identification markings for quick and easy viewing once installed.

2. Once a new mass load forces the piston to the bottom of travel (this may not occur with larger diameter pistons or small changes in the load), carefully rotate the load (see Chapter 4, Rotate the Masses), 1 to 2 turns before continuing.

3. Apply any required additional load up to an increase of 20 kilograms (4 large platters) and verify level per instructions in Chapter 4, Level the Instrument Platform.

4. Increase the pressure until the piston is floating, and repeat the procedure in Chapter 4, Load the Masses, until the desired load and pressure are obtained.

Rotate the Masses

To generate precise pressures with the RUSKA 2485 deadweight gauge the masses must be rotating. For manual rotation of the masses (the drive motor is disabled by removing the roller pin), slowly begin rotation of the mass stack carefully increasing to approximately 20 revolutions per minute (3 seconds per revolution). Hand rotation should be accomplished by grasping the sleeve weight near its top surface and rotating. For motorized rotation, simply engage the motor by depressing the drive motor power switch. For motorized operation the roller pin must be installed in the drive sleeve assembly. Refer to Figures 3-1 through 3-3 for locating the roller pin and drive motor power switch.

Fine Load Adjustment

When the RUSKA 2485 is used to generate a specific pressure, a small adjustment of the load may be required. This adjustment, to compensate for conditions such as local gravity, air buoyancy and temperature, is typically performed through the use of a laboratory mass set with denominations from 100 grams to 10 milligrams. This load adjustment is placed directly on the mass loading table and should be removed prior to changing the load to generate a subsequent pressure.

Adjust Float Position

Once the desired load is applied to the piston, use the hand pump to adjust the pressure so that the piston is slightly above the mid-float position. As the system stabilizes, the normal sink rate of the piston will carry it through mid-float.

The mid-float position can be measured manually or electronically. When the bottom edge of the hanger mass (sequence 01) bisects the float position line located just above the pulley on the drive sleeve, the piston is at mid-float. The position of the hanger mass can be observed in the float position mirror block assembly mounted on the instrument platform, as shown in Figures 3-1 and 3-4. A more accurate measurement of float position can be made using the electronic float position option.

Assess Stability

The operator must make a judgment as to the stability of the pressure system and allow adequate time for the thermal effects of pressurization to diminish. For high precision pressure measurements the stabilization period may be in excess of 20 minutes.

One indication of the relative stability of the system is the rate at which the piston descends into the cylinder. In a system that has just been pressurized, the rate of piston descent, or sink rate, will be relatively rapid and may be excessive. This is the same indication as when the pressure system is leaking, except that, with time, a leak free system will attain equilibrium and the sink rate will return to normal.

A rapid decrease in pressure will result in an abnormally slow sink rate. This thermal effect can be so great that the piston will actually rise in the cylinder until the system approaches equilibrium.

Any abnormal sink rate is an indication of instability in the pressure or leaks in the system. During the thermal stabilization period, adjust the hand pump as necessary to maintain the float position of the piston. In addition, the temperature of the piston may change slightly during the stabilization period and any fine load adjustment applied in Chapter 4, Fine Load Adjustment, to correct for thermal effects should be re-evaluated just prior to the final pressure measurement.

Execute Pressure Measurement

Once the appropriate load is applied, the thermal effects have adequately diminished and the piston is rotating at the mid-float position, a pressure measurement can be made with confidence.

Next Pressure

Once a pressure measurement is complete, carefully stop the rotation of the mass stack. Repeat the steps in Chapter 4, Load Other Masses, through section Execute Pressure Measurement, for each desired pressure. When changing the deadweight gauge pressure to a higher level, first increase the load, then increase the pressure. When descending to a lower pressure, first reduce the pressure, then reduce the load.

⚠ Caution

When removing masses from the deadweight gauge while the system is pressurized, the piston may rise to the top of travel. This movement must be anticipated and controlled to prevent damage to the equipment.

Return to Atmosphere

When all pressure measurements have been made, return the instrument to atmospheric pressure. Unload the masses from the deadweight gauge and store them in the appropriate location.

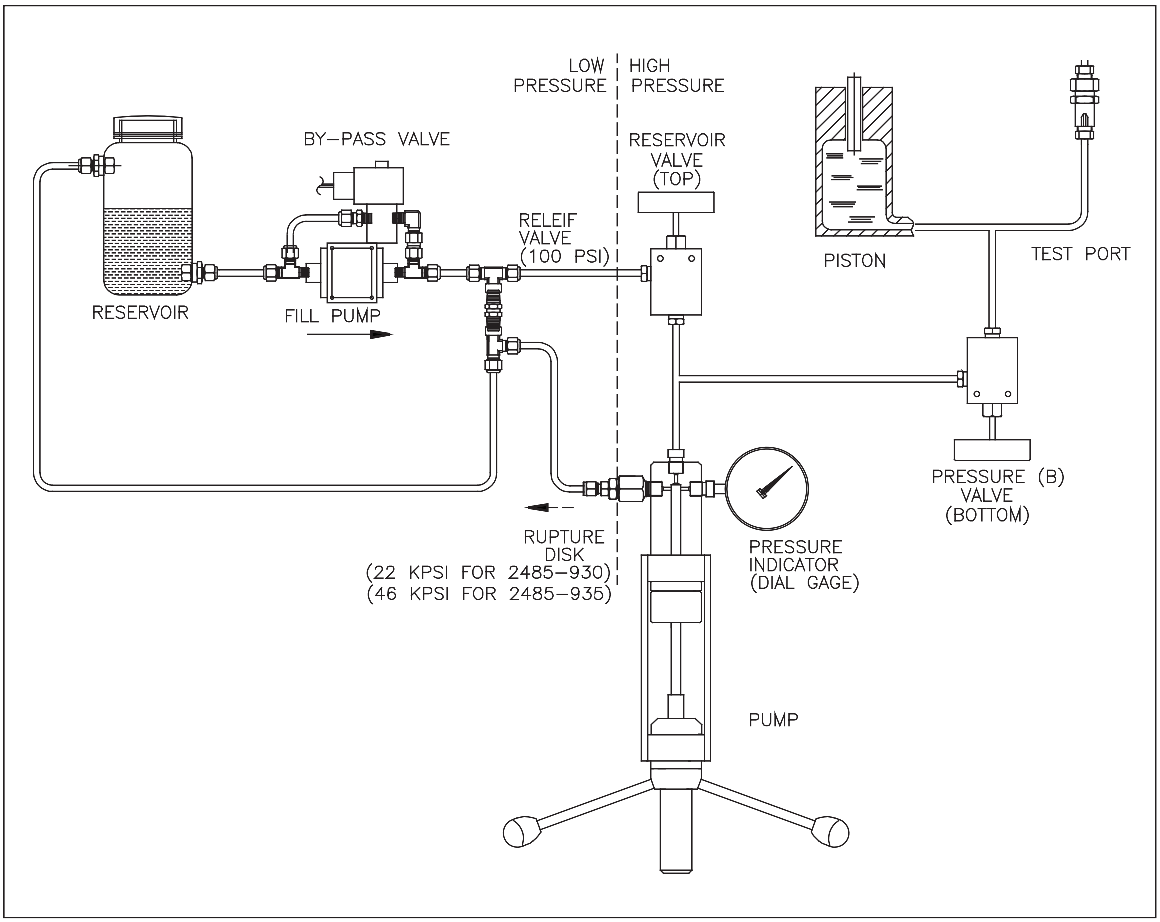


Figure 4-1. Lo and Mid Press Plumping Schematic

Preparation for Storage/Shipping — RUSKA 2485-930 and RUSKA 2485-950

When the RUSKA 2485 deadweight gauge is not in use, the pressure should be removed and the appropriate valves open to the reservoir. The following section describes the recommended steps to prepare the instrument platform for shipment or long term storage.

1. Remove all the masses loaded on the deadweight gauge, including the hanger mass. Install the shipping plug according to Chapter 4, Piston/Cylinder Identification.
2. Fully recharge the hand pump and generate approximately 2,000 psi (140 bar) as per Chapter 4, Valve Operating Procedure for RUSKA 2485-930/RUSKA 2485-935.8 for RUSKA 2485-930 or Chapter 4, Valve Operating Procedure for RUSKA 2485-950.
3. Without rotating the hand pump spindle, remove the handles from the hand pump. This will ensure that no air becomes trapped in the system during shipment or storage.

⚠ Warning

If a liquid in glass thermometer is being used, remove it from the base and package it separately for shipment or storage.

⚠ Warning

The maximum pressure rating for the low pressure shipping plug is 20,000 psi (1400 bar). Do not exceed this pressure with the low pressure shipping plug installed.

4. Rotate the reservoir source valve, on the rear of the instrument platform, ONE-QUARTER TURN.
5. Remove the oil from the internal reservoir down to a level flush with the fitting at the bottom of the reservoir.
6. Wipe any excess oil from the base plate and pressure housing.
7. Remove, clean and store the reservoir cover and the oil drain cups.
8. Place a clean, dry paper wiper in the internal reservoir to prevent contamination of the reservoir.
9. Place a small strip of soft open cell foam, approximately 1 cm x 1 cm x 10 cm, around the bottom of the mass loading table assembly between the table top and the retaining nut. This will prevent the mass loading table assembly from vibrating during transport.

Valve Operating Procedure — RUSKA 2485-930

(See Plumbing Schematic, Figure 4-1.) This section describes the proper valve operating procedures for the various functions of the RUSKA 2485-930 deadweight gauge instrument platform.

⚠ Caution

The operator of any pressurized equipment must always be aware of the condition and status of the equipment to avoid the risk of damage and personal injury.

Recharging the Hand Pump at Atmospheric Pressure

With reservoir valve A open, rotate the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit. Rotate the hand pump spindle clockwise approximately one-quarter turn to remove the spindle nut backlash.

Pressurizing the System

Close reservoir valve A and rotate the hand pump spindle clockwise. If the pressure system is sealed and no air is trapped in the hydraulic system, the pressure should begin to increase within one-quarter turn of the hand pump spindle. Refer to Chapter 5, Troubleshooting Common Problems, for troubleshooting.

Adjusting Float Position

1. As the pressure approaches that required to float the piston, reduce the rate of hand pump spindle rotation and slowly approach the proper float position.
2. If the float position or system pressure is too high, rotate the hand pump spindle counter-clockwise until the proper pressure or float position is obtained.
3. Rotate the hand pump spindle an additional one-quarter turn counter-clockwise and then carefully clockwise to restore the pressure or float position and to remove any spindle nut backlash. This will prevent the pump plunger from creeping out of the pump housing, which could result in erroneous pressure readings.

Recharging the Hand Pump While At Pressure

On occasion, the hand pump will reach the full clockwise travel limit preventing further pressurization. The hand pump may be recharged while the system remains at pressure.

1. To recharge the hand pump while the system is at pressure, verify that pressure valve B is open and note the system pressure indicated on the pressure monitor.
2. Close pressure valve B and carefully rotate the hand pump spindle counter-clockwise until the piston is at the lower travel limit and the pressure monitor indicates between zero and 500 psi (35 bar).
3. Open reservoir valve A and continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
4. Rotate the hand pump spindle clockwise one-quarter turn and close reservoir valve A.
5. Carefully rotate the hand pump spindle clockwise to generate pressure.
6. Once the pressure monitor indicates the same pressure noted earlier, slowly open pressure valve B.

Discharging the Hand Pump While At Pressure

When reducing pressure in the system, the pump may reach the counter-clockwise travel limit before the desired pressure is obtained. To allow further depressurization of the system the hand pump may be discharged while the system remains at pressure. To discharge the hand pump while the system is at pressure:

1. Verify that pressure valve B is open and adjust the hand pump position so that approximately one-quarter of the pump travel remains in the counter-clockwise direction. Note the system pressure indicated on the pressure monitor.
2. Close pressure valve B and carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
3. Open reservoir vale A and rotate the hand pump spindle clockwise until approximately one-quarter of the pump travel remains in the clockwise direction.
4. Close reservoir valve A and carefully rotate the hand pump spindle clockwise to generate pressure.
5. Once the pressure monitor indicates the same pressure noted earlier, slowly open pressure valve B.

Returning to Atmosphere

1. Verify that pressure valve B is open.
2. Rotate the hand pump spindle counter-clockwise until the piston is at the lower travel limit and the pressure monitor indicates between zero and 500 psi (35 bar).
3. Slowly open reservoir valve A.

Valve Operating Procedure — RUSKA 2485-950

(See Plumbing Schematic Figure 4-2.) This section describes the proper valve operating procedures for the various functions of the RUSKA 2485-950 deadweight gauge instrument platform.

⚠ Warning

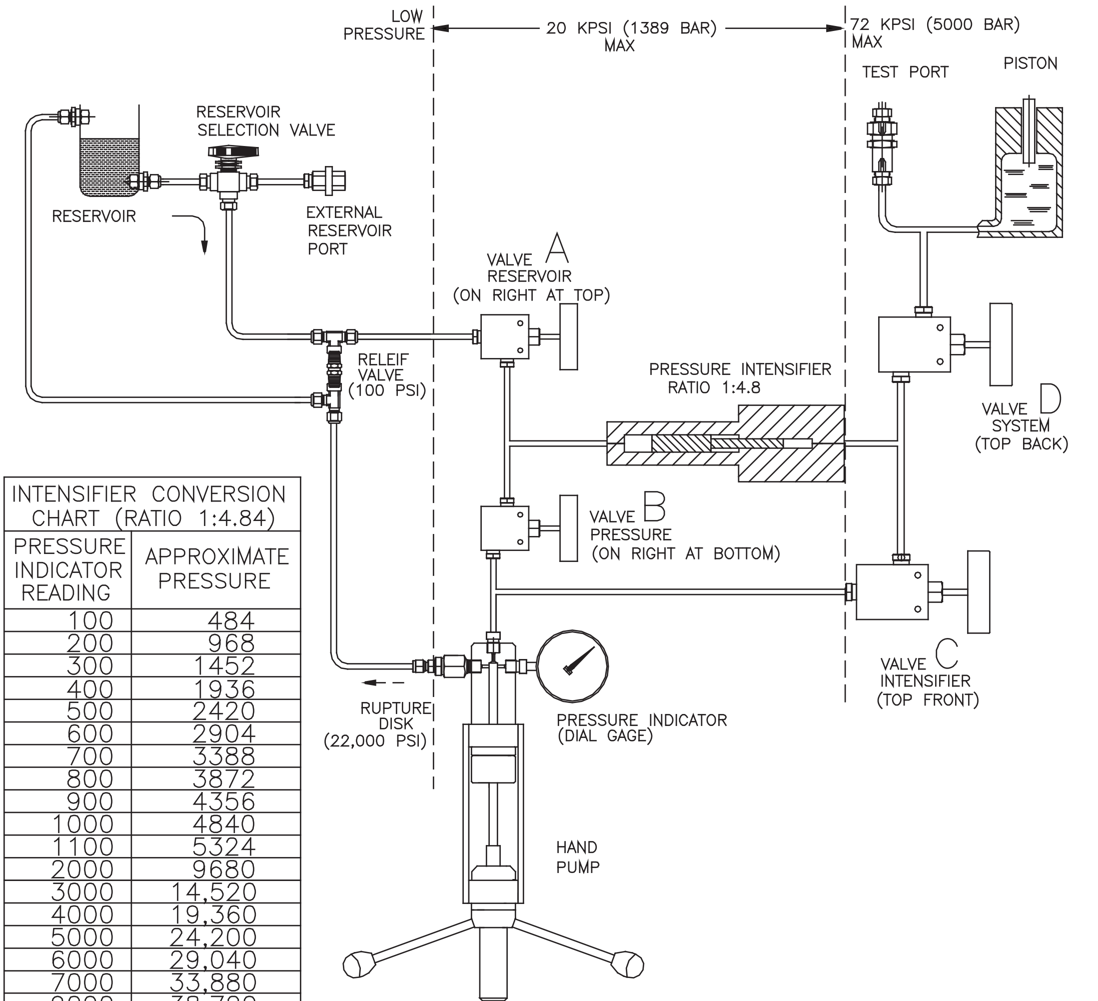
The operator of any pressurized equipment must always be aware of the condition and status of the equipment to avoid the risk of damage and personal injury.

⚠ Caution

Reservoir valve A and pressure valve B perform different functions in the RUSKA 2485-930 and RUSKA 2485-950 instrument platforms. The valve operating procedures for the RUSKA 2485-930 should not be used when operating the RUSKA 2485-950.

The following procedures reference the valve positions "open" and "closed". The operator must manipulate the valves in such a way that their status can easily be determined. When the procedure refers to opening a multi-turn valve, the valve should not be allowed to remain in the full open state, rather, if it has been fully opened, it should then be closed approximately one-half turn.

If a valve is positioned at any place between nearly-full-open and approximately one-half turn open, the operator can assess the "open" status of the valve by simply rotating the handle in either direction. If the valve has been left in the full-open position, it will be difficult to determine whether the valve is open or closed. If the valve is closed and the operator believes it to be open, permanent damage to the valve seat can occur if the stem is over-torqued.



INTENSIFIER CONVERSION CHART (RATIO 1:4.84)

PRESSURE INDICATOR READING	APPROXIMATE PRESSURE
100	484
200	968
300	1452
400	1936
500	2420
600	2904
700	3388
800	3872
900	4356
1000	4840
1100	5324
2000	9680
3000	14,520
4000	19,360
5000	24,200
6000	29,040
7000	33,880
9000	38,720
10,000	43,560
11,000	48,400
12,000	58,080
13,000	62,920
14,000	67,760
15,000	72,600

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Figure 4-2. Hi Pressure Plumbing Schematic

Note

Whenever operating the valves, use only the minimum torque required to close the valve, and open the valve very slowly when there is a differential pressure across the valve.

Recharging the Hand Pump While at Atmosphere

With reservoir valve A and pressure valve B open, rotate the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit. Rotate the hand pump spindle clockwise approximately one-quarter turn to remove any spindle nut backlash.

Generating Pressures to 20,000 PSI (1400 Bar)

Pressurizing the System

Open valve A, C, and D. Close pressure valve B and rotate the hand pump spindle clockwise. If the pressure system is sealed and no air is trapped in the hydraulic system, the pressure should begin to increase within one-quarter turn of the hand pump spindle. Refer to Chapter 5, Troubleshooting Common Problems, for troubleshooting.

Adjusting Float Position

As the pressure approaches that required to float the piston, reduce the rate of hand pump spindle rotation and slowly approach the proper float position.

If the float position or system pressure is too high:

1. Rotate the hand pump spindle counter-clockwise until the proper pressure or float position is obtained.
2. Rotate the hand pump spindle an additional one-quarter turn counter-clockwise and then carefully clockwise to restore the pressure or float position and to remove any spindle nut backlash. This will prevent the pump plunger from creeping out of the pump housing, which could result in erroneous pressure readings.

Recharging the Hand Pump While at Pressure

On occasion, the hand pump will reach the full clockwise travel limit preventing further pressurization. The hand pump may be recharged while the system remains at pressure.

To recharge the hand pump while the system is at pressure:

1. Close intensifier valve C and note the pressure indication on the pressure monitor.
2. Rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar) and open pressure valve B.
3. Continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
4. Rotate the hand pump spindle clockwise one-quarter turn and close pressure valve B. Carefully rotate the hand pump spindle clockwise to generate pressure.
5. Once the pressure monitor indicates the same pressure noted earlier, slowly open intensifier valve C.

Discharging the Hand Pump While at Pressure

When reducing pressure in the system, the pump may reach the counter-clockwise travel limit before the desired pressure is obtained. To allow further depressurization of the system the hand pump may be discharged while the system remains at pressure.

To discharge the hand pump while the system is at pressure:

1. First verify that reservoir valve A, intensifier valve C and system valve D are open, then adjust the hand pump position so that approximately one-quarter of the pump travel remains in the counter-clockwise direction.

2. Close intensifier valve C and note the system pressure indicated on the pressure monitor for use later in this section.
3. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
4. Open pressure valve B and rotate the hand pump spindle clockwise until approximately one-quarter of the pump travel remains in the clockwise direction.
5. Close pressure valve B and carefully rotate the hand pump spindle clockwise to generate pressure.
6. Once the pressure monitor indicates the same pressure noted earlier in this section, slowly open intensifier valve C.

Returning to Atmosphere

Rotate the hand pump spindle counter-clockwise until the piston is at the lower travel limit and the pressure monitor indicates between zero and 500 psi (35 bar), then slowly open pressure valve B.

Generating Pressures Greater than 20,000 PSI (1400 Bar)

⚠ Caution

Although not essential, it is recommended that the procedure in Chapter 4, Generating Pressure Greater than 20,000 Psi (1400 Bar), be followed to generate approximately 20,000 psi (1400 bar) to pre-charge the intensifier prior to proceeding with the procedure. If the low pressure procedure is not performed first, the likelihood of recharging the intensifier while at pressure is much greater.

Generating Pressure

Generate between 18,000 and 20,000 psi (1250 and 1400 bar) using the procedure described in Chapter 4, Generating Pressure Greater than 20,000 Psi (1400 Bar).

1. Close intensifier valve C and carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
2. Open pressure valve B and rotate the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
3. Rotate the hand pump spindle clockwise approximately one-quarter turn to remove any spindle nut backlash.
4. Close reservoir valve A and rotate the hand pump spindle clockwise to generate pressure.

As pressure develops in the hand pump it will increase rather rapidly until the intensifier plunger begins to move. At this point the intensifier will begin to increase the pressure in the test port. As the intensifier builds pressure in the high pressure system, the pressure monitor will also indicate an increase in the low pressure system, but not at the same rate as before the intensifier plunger began to move. This is due to the intensifier plunger movement changing the volume of the low pressure system.

The relative rate of pressure change in the hand pump, as indicated by the pressure monitor is an important indication in the operation of the system. If the pressure rate does not change at the appropriate pressure, according to the intensifier ratio, the intensifier has reached the high pressure travel limit and must be recharged before continuing. Refer to Chapter 4, for instructions on recharging the intensifier.

Note

The basic intensifier ratio is 4.7:1. The actual pressure ratio will be slightly different due the friction of the seals in the intensifier.

Adjusting Float Position

As the pressure approaches that required to float the piston, reduce the rate of hand pump spindle rotation and slowly approach the proper float position.

If the float position or system pressure is too high:

1. Rotate the hand pump spindle counter-clockwise until the proper pressure or float position is obtained.
2. Rotate the hand pump spindle one additional turn counter-clockwise and then carefully clockwise to operate the intensifier and adjust the float position.

This will provide better control of the float position by remove any spindle nut backlash and developing enough pump pressure to overcome the friction of the seals in the intensifier.

Recharging the Hand Pump While at Pressure

On occasion, the hand pump will approach the full clockwise travel limit while the system is under pressure. The hand pump may be recharged while the system remains at pressure.

To recharge the hand pump while the system is at pressure:

1. Close system valve D and note the system pressure indicated on the pressure monitor.
2. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
3. Open reservoir valve A and continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
4. Rotate the hand pump spindle clockwise one-quarter turn and close reservoir valve A.
5. Carefully rotate the hand pump spindle clockwise to generate pressure.
6. Once the pressure monitor indicates the same pressure noted earlier, slowly open system valve D.

Recharging the Intensifier While at Pressure

On occasion, the intensifier will reach the full stroke limit while the system is under pressure. The intensifier may be recharged while the system remains at pressure.

There are two indications to the operator when the intensifier plunger has reached the full stroke limit. If the intensifier is at full stroke prior to closing intensifier valve C for high pressure operation, as described in Chapter 4, the pressure monitor indication will not change in rate as the pump pressure approaches approximately one-fifth the test port pressure. The more typical indication is that when the intensifier plunger reaches the full stroke limit while pressurizing the test port, the pressure monitor will indicate a sudden increase in the rate of pressurization. The pressure at which this occurs is important to the following procedure.

To recharge the intensifier while the system is at pressure:

1. Note the pump pressure as described above and close system valve D.
2. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
3. Open reservoir valve A and continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
4. Rotate the hand pump spindle clockwise one-quarter turn.
5. VERY SLOWLY open intensifier valve C.
6. Close pressure valve B and rotate the hand pump spindle clockwise.

As the pump begins to develop pressure, the intensifier plunger will move towards the low pressure end of travel. Continuing the rotation of the hand pump will force the intensifier plunger to the fully recharged position as indicated by a sudden increase in the pressure indicated on the pressure monitor.

7. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar) and open pressure valve B.
8. Continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
9. Rotate the hand pump spindle clockwise one-quarter turn and close reservoir valve A and intensifier valve C.
10. Carefully rotate the hand pump spindle clockwise to generate pressure.
11. Once the pressure monitor indicates the same pressure noted earlier in this section, slowly open system valve D.

Discharging the Intensifier While at Pressure

If the intensifier was recharged while at pressure, it is likely that during depressurization the intensifier will reach the return stroke limit while the system remains pressurized. The intensifier may be discharged while the system remains at pressure to allow further depressurization of the system.

The indication to the operator that the intensifier plunger has reached the return stroke limit is that the pressure monitor will indicate a sudden increase in the rate of depressurization. The pressure at which this occurs is important to the following procedure.

To discharge the intensifier while the system is at pressure:

1. Note the pump pressure as described above, except that the hand pump spindle must be rotated clockwise until the intensifier again begins to pressurize the test port. This condition will be indicated when the pressure monitor shows a sudden decrease in the rate of re-pressurization. Note this pressure monitor reading for use later in this procedure.
2. Close system valve D and carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
3. Open reservoir valve A, then VERY SLOWLY open intensifier valve C.
4. Continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
5. Rotate the hand pump spindle clockwise one-quarter turn and close reservoir valve A.

6. Rotate the hand pump spindle clockwise until the intensifier plunger reaches the full stroke limit. This may require as much as 26 full rotations of the hand pump spindle. The indication that the intensifier plunger has reached the full stroke limit is that the pressure monitor will indicate a rapid increase in pump pressure.
7. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
8. Open reservoir valve A and continue rotating the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
9. Rotate the hand pump spindle clockwise one-quarter turn and close pressure valve B.
10. Rotate the hand pump spindle clockwise TWO FULL TURNS.
11. Open pressure valve B and close reservoir valve A and intensifier valve C.
12. Rotate the hand pump spindle clockwise to generate pressure.
13. Continue to rotate the hand pump spindle clockwise until the pressure monitor indicates the pressure noted earlier in this section, then slowly open system valve D.
14. Rotate the hand pump spindle counter-clockwise to continue reducing the system pressure.

Discharging the Hand Pump While at Pressure

When reducing pressure in the system, the hand pump may reach the counter-clockwise travel limit before the desired pressure is obtained. To allow further depressurization of the system, the hand pump may be discharged while the system remains at pressure.

To discharge the hand pump while the system is at pressure:

1. Verify that pressure valve B is open and adjust the hand pump position so that approximately one-quarter of the pump travel remains in the counter-clockwise direction.
2. Close system valve D and note the system pressure indicated on the pressure monitor.
3. Carefully rotate the hand pump spindle counter-clockwise until the pressure monitor indicates between zero and 500 psi (35 bar).
4. Open reservoir valve A and rotate the hand pump spindle clockwise until approximately one-quarter of the pump travel remains in the clockwise direction.
5. Close reservoir valve A and carefully rotate the hand pump spindle clockwise to generate pressure.
6. Once the pressure monitor indicates the same pressure noted earlier in this section, slowly open system valve D.

Returning to Atmosphere

1. Carefully rotate the hand pump spindle counter-clockwise until the piston is at the lower travel limit and the pressure monitor indicates between zero and 500 psi (35 bar).
2. Slowly open reservoir valve A.
3. Continue to rotate the hand pump spindle counter-clockwise until the pump position indicator approaches the counter-clockwise travel limit.
4. VERY SLOWLY open intensifier valve C.
5. Remember to recharge intensifier before proceeding.

Optional Hardware

This section describes the electronic float position, and electronic temperature sensor options.

Electronic Float Position

The electronic float position option is used to provide high resolution indication of the float position and sink rate of the piston. The electronic float position option can increase the reliability and precision of pressure measurements made using the deadweight gauge. The electronic float position sensor assembly is installed on the instrument platform below the masses. The adjustment and calibration procedures for the electronic float position sensor are included in the operating manual for the display device.

Electronic Temperature Sensor

The electronic temperature option uses a platinum resistance thermometer (PRT) in conjunction with an electronic display device, such as the electronic float position display, to provide a reliable digital indication of the deadweight gauge temperature. The PRT is mounted in the main pressure housing of the deadweight gauge, in place of the liquid-in-glass thermometer used when this option is not installed. The adjustment and calibration procedures for the electronic temperature option are included in the operating manual for the display device.

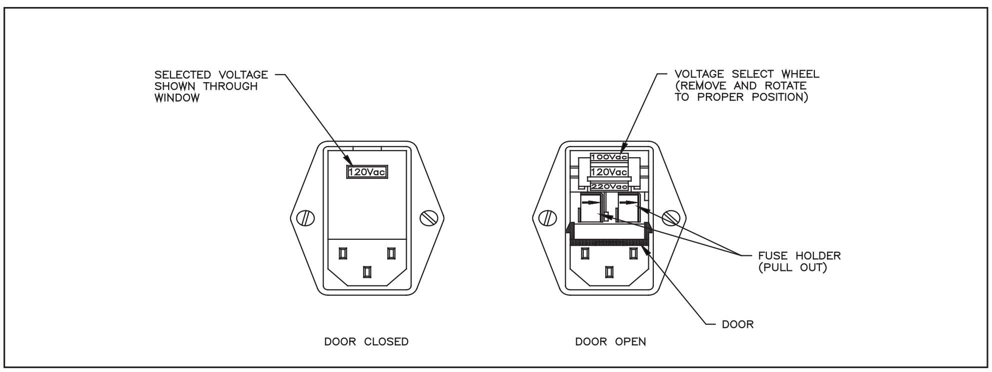

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Figure 4-3. Voltage Selector Switch

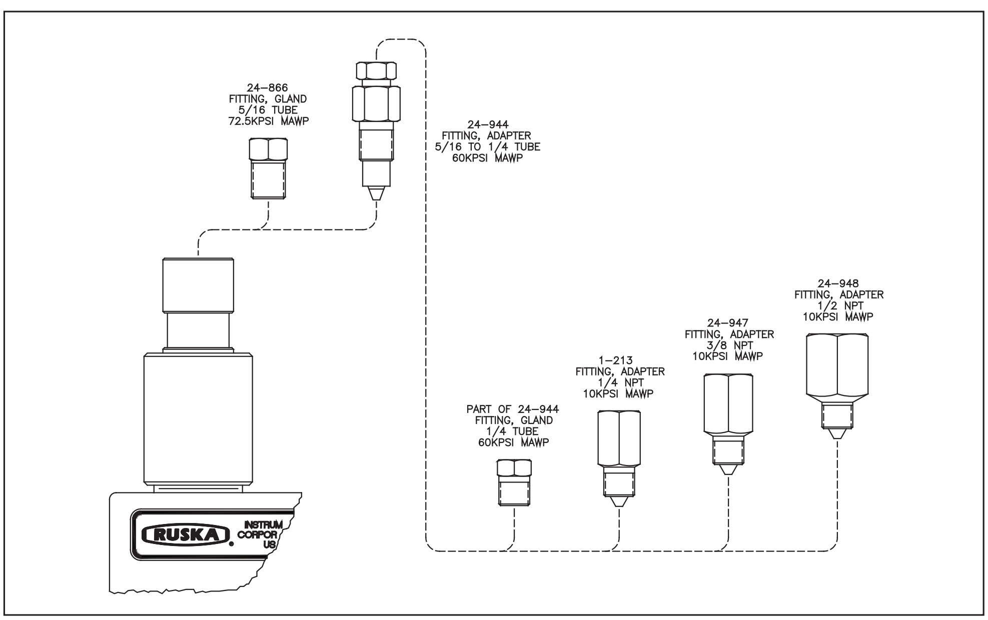

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Figure 4-4. Test Port Manifold and Adapters

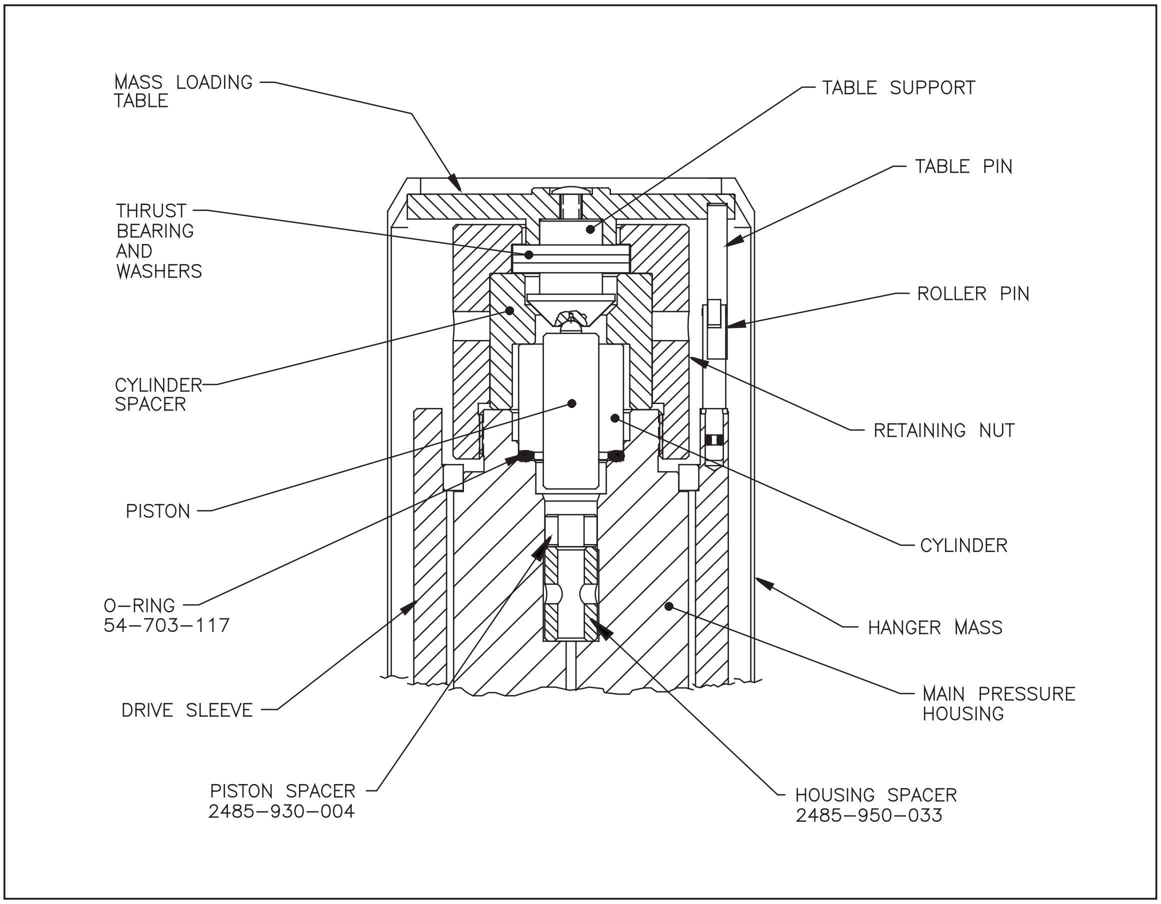

Figure 4-5. Mass Loading Table (Installed)

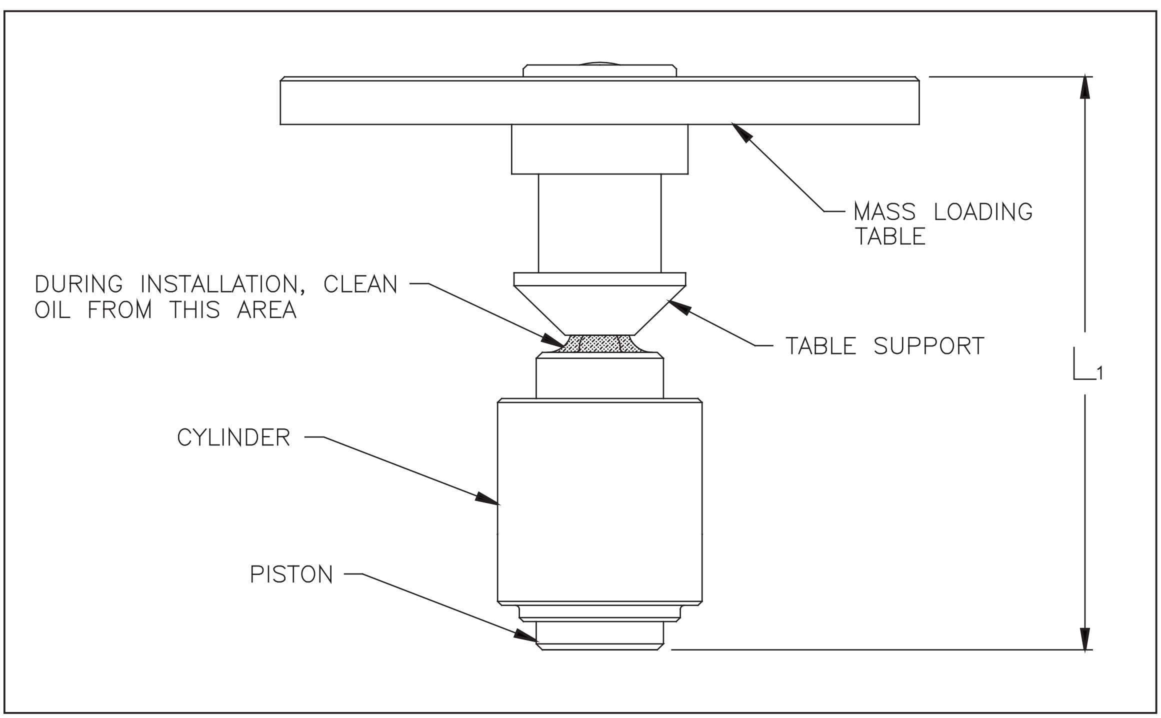

Figure 4-6. Mass Loading Table and Piston

Chapter 5
Maintenance and Troubleshooting

Introduction

When operated according to the recommended procedures, the RUSKA 2485 deadweight gauge requires only minimal maintenance to sustain operation for extended periods. The most important factor in the operation of the instrument is diligent and methodical handling of the piston/cylinder assemblies and the mass set. Improper use will lead not only to unexpected maintenance and repair, but can also increase the risk of injury to the operator. Following the guidelines in this section will minimize the risk of damage to the instrument and injury to the operator, and will prolong the life of the instrument.

There are several deadweight gauge performance characteristics described in the following sections that should be expected during normal operation. These include pressurization rates, sink rates and others. If the instrument fails to provide such feedback to the operator, the condition should be investigated prior to continued operation of the instrument. Refer to Chapter 5, Troubleshooting Common Problems, for troubleshooting.

Maintenance

This section describes the maintenance steps required to preserve the performance of the deadweight gauge system, including the instrument platform, the mass set and the piston/cylinder assemblies. Although the maintenance requirements for this system are minimal, those that relate to the routine handling are critical to the longevity and reliability of the instrument.

Instrument Platform Maintenance

The instrument platform requires little maintenance. Functional integrity and esthetic preservation are primarily the result of careful manipulation of the instrument. Several components, however, may require occasional verification, adjustment or repair.

Oil Drain Hose

Route the oil drain hose to an appropriate container.

Instrument Platform Cleaning

Occasionally, oil or other contamination will accumulate in various locations on the instrument platform. Wipe any contamination and accumulated oil from the top and bottom surfaces of the instrument platform. The instrument cover may require removal to adequately clean the instrument platform. Refer to Chapter 5, Instrument Cover Removal and Replacement, for instructions on removing the instrument cover.

Level Vial Adjustment

Optimum performance and reliability of the pressure measurements made using a deadweight gauge rely on the piston axis being vertical. When properly adjusted, the level vial mounted to the instrument platform is a simple and reliable reference. Proper adjustment of the level vial should be verified periodically.

If the main pressure housing or level vial has been removed or damaged, readjustment of the level vial may be necessary. The level vial should be adjusted such that, when the bubble in the level vial is centered, the top surface of the main pressure housing is level within 5 minutes of arc.

Instrument Platform Lubrication

Several components of the instrument platform may require periodic lubrication to provide reliable, enduring service. A drop or two of light machine oil in the threads and swivel sockets of the support legs may be required when the instrument is placed in service and every few years thereafter.

The hand pump spindle and spindle nut bearings require lubrication to operate properly. Both are lubricated at the factory, but require inspection when the instrument is placed in service and every few years thereafter. Remove the pump lubrication port cover (Figure 3-4), add 2-3 drops of clean 90W to 140W oil, and replace the pump lubrication port cover.

During operation of the deadweight gauge, the oil passing through the minute clearance between the piston and cylinder, and the overflow oil during piston/cylinder exchange, will provide lubrication for the drive sleeve bushings. When the instrument is placed in service and during each piston/cylinder exchange (when the mass loading table assembly has been removed) verify that the drive sleeve bushing has an ample amount of lubrication.

Packing Adjustment for Valves

1. Remove all pressure from the system (all valves open).
2. Remove the instrument covers.
3. Open the valve to the maximum open position.
4. Loosen the packing gland locking device.
5. Use a torque wrench to tighten the packing gland to 60 FT-LBS (81.3 N-M). If a torque wrench is not available, tighten the packing gland approximately 1/16 turn.
6. Pressurize the system and check for leaks.
7. If the packing still leaks, relieve all pressure from the system and repeat steps 2 thru 5. If packing does not seal after several attempts, it needs to be replaced. Contact Fluke for parts and procedures.
8. Reinstall the packing gland locking device.
9. Reinstall the instrument covers.

Rupture Disk Replacement

If the pressure in the hand pump exceeds the rating of the rupture disk in the safety head, the rupture disk will burst and must be replaced with one of the same rating before the instrument can safely be returned to service. Refer to Appendix B for the part number and rating of the rupture disk. Replace the rupture disk according to the following instructions.

⚠ Caution

Do not attempt to recharge the hand pump until the rupture disk has been replaced as air will be pulled into the hydraulic system.

1. Remove the instrument cover according to Chapter 5, Instrument Cover Removal and Replacement.
2. Close reservoir valve A and pressure valve B, and if applicable (RUSKA 2485-950) intensifier valve C.
3. Remove the tubing from the reservoir end of the safety head (Figure 5-1).
4. Remove the safety head from the hand pump housing.
5. Remove the torque nut from the main body and extract the spent rupture disk.
6. Insert the new rupture disk into the body, replace the hold down ring and torque nut and torque to between 100 and 110 foot-pounds.
7. Fill the end of the safety head assembly opposite the reservoir plumbing with clean deadweight gauge oil and install the safety head assembly into the hand pump housing, but do not tighten.
8. Slowly rotate the hand pump spindle clockwise until oil seeps from the safety head mounting port (see note below).
9. Carefully tighten the safety head assembly to the hand pump housing and replace the reservoir tubing on the opposite end of the safety head assembly. Refer to Chapter 5, Troubleshooting Common Problems, for troubleshooting leaks and air trapped in the system.

Note

If the hand pump does not have enough travel to force oil through the safety head port, temporarily tighten the safety head assembly and recharge the hand pump per Chapter 4, Valve Operating Procedure for RUSKA 2485-930/RUSKA 2485-935; or Valve Operating Procedure for RUSKA 2485-950. Loosen the safety from the hand pump housing and rotate the hand pump spindle to force oil through the safety head port.

Instrument Cover Removal and Replacement

Several aspects of the instrument platform maintenance require removal of the instrument cover. This section describes the steps necessary to remove and reinstall the instrument cover.

1. Remove the test port manifold and nut per Chapter 4, Test Port Manifold Connections.
2. Close the appropriate valve to isolate the reservoir from the system.
3. Remove the handles from valves A and B, the reservoir source valve, and if applicable, (RUSKA 2485-950) valves C and D.
4. Remove the screws securing the instrument covers and carefully lift the cover sections from the instrument platform.

Note

The RUSKA 2485 can be safely operated without the instrument covers.

Reinstallation of the instrument cover is performed in the reverse order described above. Before reinstalling the cover, wipe any excess oil from the instrument platform, plumbing and valves. Do not tighten the instrument cover mounting screws until all the screws have been installed.

Seal and O-ring Replacement

After some period of use, the seals and o-rings in the instrument platform may deteriorate and begin to leak. Refer to Chapter 5, Troubleshooting Common Problems, for troubleshooting leaks. Refer to Chapter 4, Test Port Manifold Connections; and Piston Cylinder Assemblies, for replacing worn seals and o-rings on the piston/cylinder assemblies and test port manifold assembly. Replacement of the seals in the valves, hand pump and intensifier (RUSKA 2485-950 only) is beyond the scope of this manual.

Piston/Cylinder Cleaning

Optimum performance of a deadweight gauge requires a functional piston/cylinder assembly. The piston/cylinder assembly must be clean to operate properly and preclude permanent damage. Typically, hydraulic piston/cylinder assemblies, once clean, and when handled properly, will not likely require periodic cleaning.

Deliberate and careful handling, and proper storage of a piston/cylinder assembly, in the storage container or main pressure housing, will prolong the life of the assembly and help to prevent contamination. Should a piston/cylinder become contaminated, however, it must be cleaned before resuming operation.

The piston/cylinder cleaning procedure is as follows:

1. Fold or twist several light duty wipers (Kimberly-Clark Type 900S Kimwipes™ recommended), as shown in Figures 5-2 and 5-3, for removing excess oil from the piston and cylinder and for drying parts later in the procedure. Wipe the excess oil from the parts. Wetting the wipers with a mild solvent such as high grain alcohol or acetone may be helpful.
2. Using a clean bottle brush (part number 7-682) for the low range cylinder and medium duty paper wipers for other parts, thoroughly scrub the piston and cylinder with soap (Cashmere Bouquet™) and lukewarm water. Thoroughly rinse the parts and quickly dry with the folded or twisted wipers.
3. Set the parts aside for 15 minutes prior to assembly. Coat the bottom of the piston in clean deadweight gauge oil and carefully insert the piston into the cylinder. Place the piston/cylinder assembly into the storage container, cover with clean deadweight gauge oil and secure the top of the container.

Alternate Piston/Cylinder Cleaning Method

If soap and water are not available, the piston/cylinder assemblies may be cleaned with a mild solvent such as high grain alcohol or acetone, provided no residues remain on the parts prior to assembly. This process may not yield as consistent results as cleaning with soap and water.

Mass Set Cleaning

It is recommended that the deadweight gauge masses be handled using clean gloves, such as number 99189 included in the 2485-202 or 2485-203 set-up kit. Should the masses become contaminated, they may be cleaned using a mild solvent, such as high grain alcohol, or using soap and water, provided that they are thoroughly dried afterwards.

Troubleshooting Common Problems

Air Trapped in the System

Air trapped in a hydraulic system can be more than an annoyance. When a substantial amount of air is trapped in the system, the system may become virtually inoperable. The high compressibility of the air prevents significant pressure from building in the system until the air has been adequately compressed. This condition may "use up" a substantial portion of the available hand pump travel. A system with little or no trapped air, however, will require only one-quarter turn of the hand pump spindle before pressure builds in the system.

If more than one-quarter turn of the hand pump spindle is required to generate pressure in the system, it may be contaminated with air. There are several other situations, besides air being trapped in the system, which can also result "slow" pressurization.

A large volume connected to the test port manifold will cause the system pressure to build more slowly than with a smaller volume attached. More of the hand pump travel, or more hand pump strokes may be required to fully pressurize a large volume.

If an instrument such as the RUSKA 2413 Differential Pressure Cell, which incorporates a diaphragm type sensor that must move to the end of a cavity before pressure builds, is attached to the system, the response of the hand pump will appear as if air is trapped in the system, but is the normal response for the application.

After confirming that air has indeed been trapped in the system, the valves can be manipulated to isolate portions of the system to determine where the greatest amount of air is trapped. Figures 4-1 and 4-2 are plumbing schematics that can be used to identify the appropriate valves to isolate segments the system.

For each segment, recharge the hand pump per Chapter 4, Valve Operating Procedure for RUSKA 2485-930/RUSKA 2485-935; or Valve Operating Procedure for RUSKA 2485-950, as appropriate.

1. Verify that the hand pump spindle backlash has been removed and close the appropriate valves to isolate the particular system segment.
2. Rotate the hand pump clockwise until pressure begins to build. If the rotation is greater than one-quarter turn of the hand pump spindle, there is a significant amount of air trapped in that segment.
3. Remove the air from that segment before proceeding to the next segment.

The hand pump segment should be tested first. If air is trapped in the hand pump, it can be removed by loosening the bleed screw located on top of the hand pump housing in front of the pressure monitor. Once the hand pump segment is free of air, continue to the next segment, which will consist of the hand pump segment plus, for example, the high pressure end of the intensifier (RUSKA 2485-950 only). Note that in this example, if the intensifier has not been recharged, as described in Chapter 4, Valve Operating Procedure for RUSKA 2485-950, it will appear that there is a large amount of air trapped in the system as the intensifier plunger is pushed to the recharge travel limit. Once the intensifier is fully recharged, recharge the hand pump and repeat the test. Air trapped in other segments may require loosening certain fittings to bleed the air from the system.

If most of the air has been removed, but that which remains eludes discharge, the system should be pressurized to several thousand psi over night. During this period, air trapped in the system will go into solution with the oil. After this time period has passed, do not decrease the pressure. Rather, slowly and carefully loosen select fittings, one at a time, to release the oil. As the oil is released, maintain the pressure using the hand pump. Continue until a significant volume of oil has passed through each of the bleed points, usually a full stroke of the hand pump is required. Release the pressure, recharge the hand pump and repeat the test.

Pressure Leaks

Eventually, every hydraulic system develops a leak. This section includes information useful in isolating such leaks in the RUSKA 2485 deadweight gauge. The first indication of a leak in a pressurized system is that the pressure decreases with time. Another measure of leaks in a pressurized deadweight gauge system is that the piston/cylinder sink rate is excessive. If the sink rate is abnormally fast, there may be a leak in the system.

If the system has only recently been pressurized, decreasing pressure and an abnormally fast sink rate are to be expected. The act of pressurization results in heating of the pressure medium. As the heat dissipates into the system, the pressure decreases. The piston/cylinder, acting as a regulator, adjusts the volume of the system attempting to maintain the pressure, resulting in the abnormal sink rate. This adiabatic effect must be allowed to dissipate before troubleshooting all but the largest of leaks.

Figures 4-1 and 4-2 are plumbing schematics that can be used to identify the appropriate valves to isolate segments the system. Most leaks in fittings will result in droplets of oil forming at the fitting, tubing or bleed port for the connection. Leaks in valves and seals may be more difficult to isolate.

Leaks in core packing of reservoir vale A and pressure valve B are usually more apparent at pressures below 500 psi (35 bar). To test these valves, install a shipping plug in the main pressure housing according to Chapter 4 and connect a pressure monitor, with 50 psi (5 bar) or better resolution, to the test port manifold.

1. Recharge the hand pump according to Chapter 4, Valve Operating Procedure for RUSKA 2485-930; or Valve Operating Procedure for RUSKA 2485-950, as applicable.
2. Verify that pressure valve B is open and, if applicable (RUSKA 2485-950), valves C and D are open.
3. Close reservoir valve A and slowly rotate the hand pump clockwise to generate approximately 100 psi. If the pressure can not be generated, there may be air trapped in the system, or there may be a leak.
4. If reservoir valve A appears to be leaking, open reservoir vale A and recharge the hand pump.
5. Verify that valve A is open and rotate the reservoir source valve ONE-QUARTER turn to a position half-way between internal and external.
6. Carefully pressurize to 100 psi, see note below.
7. If the system response is now normal, reservoir vale A leaks and must be repaired. Otherwise, remove the pressure and rotate the reservoir source valve to the appropriate position.

Note

The reservoir supply plumbing incorporates a relief valve to prevent accidental over-pressurization of the supply plumbing. The relief vale is set at the factory to 150 psi (10 bar).

For RUSKA 2485-950, repeat the above test for pressure valve B. To test pressure vale B for RUSKA 2485-930, close reservoir valve A and pressurize the system to 100 psi. Close pressure valve B and open reservoir valve A. If the pressure monitor attached to the test port manifold indicates leakage through pressure valve B, it must be repaired.

Drive Motor

If the mass stack does not rotate when power is applied to the drive motor, use the following procedure to diagnose the failure.

- If the motor does not rotate when the proper power is applied, disconnect the power, check the power setting and, if necessary, replace the fuse (refer to Chapter 4, Setting Up the Instrument Platform). If this fails, the motor may be damaged.
- If the drive motor operates properly, but the drive sleeve does not rotate, verify that the drive belt is clean, not damaged and is properly adjusted. Verify that the drive sleeve bushings are not damaged and are properly lubricated.
- If the drive motor operates properly and the drive sleeve rotates, but the mass loading table does not, verify that the roller pin is properly installed in the top of the drive sleeve (refer to Figures 3-1 through 3-3). Verify that the mass loading table assembly is properly installed and is not damaged.

Troubleshooting and Changes in Operating Voltage

Table 5-1. Troubleshooting Changes in Operating Voltage

Description	Corrective Action
Drive motor indicator lamp lights but the drive motor does not run.	Disconnect the power cord and check drive motor.
Fill pump indicator lamp lights but the fill pump does not operate.	Verify that the power pigtail that protrudes from the bottom of the drive motor housing is plugged into the fill pump housing under the back side of the base.
Replacement fuse required:	Part number 26-216, 1 amp slow-blow
Changing operating voltage	To switch voltages from 110 vac to 220 vac, disconnect the power and switch the voltage selector on the back of the unit. (Refer to figure 4-1 in the user's manual.) The unit should operate as well on 50 or 60 hz power.
Air in the system (allowing the reservoir to run dry).	The air may be removed from the system using the instructions detailed in Chapter 5, Air Trapped in the System, of the operator's manual.

Options

Electronic Float Position

If the float position of the piston/cylinder assembly is not being measured correctly by the electronic float position indicator, verify that the electrical connectors to the sensor are secure and that the sensor is properly adjusted (refer to Chapter 4, Electronic Float Position).

⚠ Caution

The hanger mass and at least one other mass 2 kilograms or larger are installed on the mass loading table. If the proper response is not obtained, the sensor or the control box may be damaged.

Electronic Temperature Sensor

If the temperature of the deadweight gauge is not being measured correctly by the electronic temperature indicator, verify that electrical connection to the sensor is secure. If the proper response is not obtained, the sensor or the control box may be damaged.

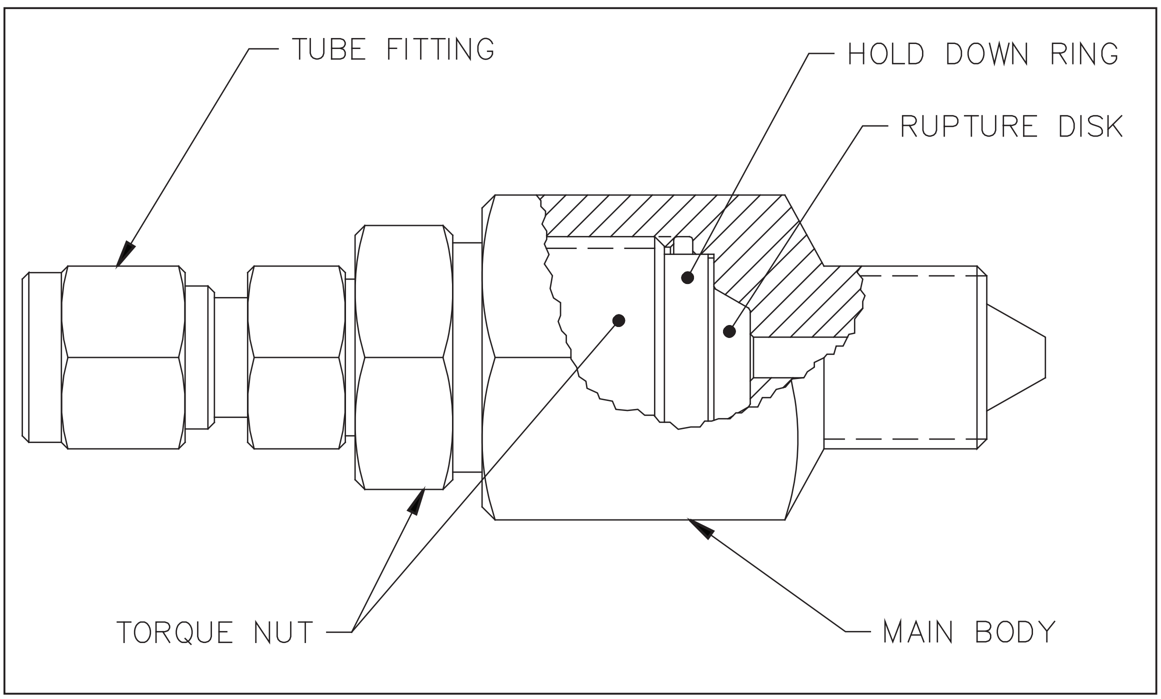

Figure 5-1. Safety Head and Rupture Disk

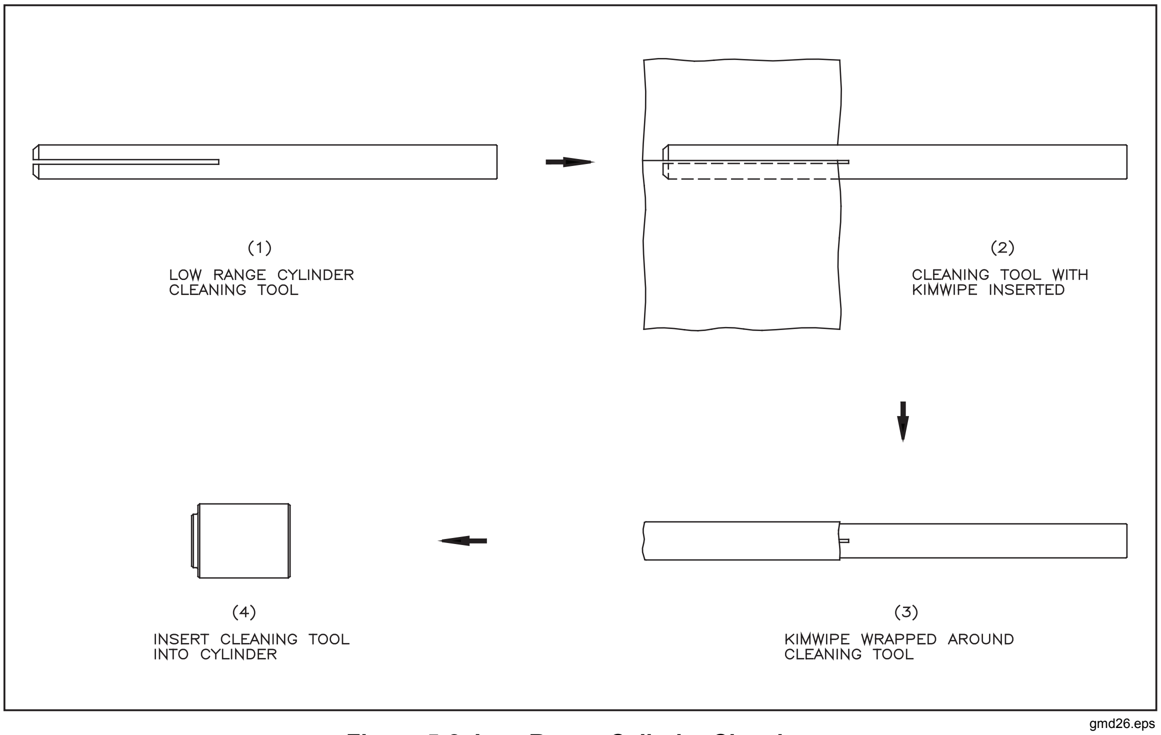

Figure 5-2. Low Range Cylinder Cleaning

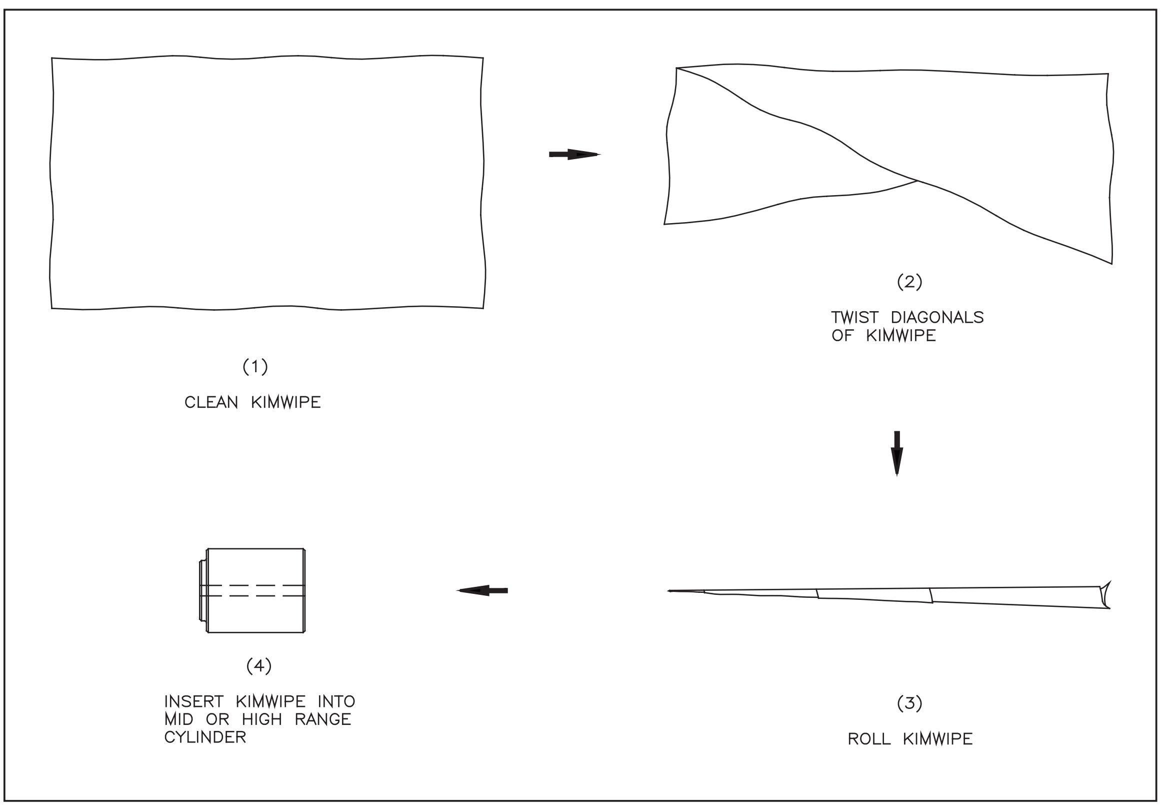

Figure 5-3. Mid/High Range Cylinder Cleaning

Appendix A
Calculations

Explanation of "Pressure Calculation Worksheet"

(Tables A9 and A11)

These tables may be used with gas and hydraulic piston pressure gauges that are operated with an atmospheric reference or vacuum reference. P_A represents the pressure at the piston reference gauge level, P_β represents the pressure desired at the device under test, and P_H is the head pressure created by the pressure medium and the difference in height between the piston pressure gauge and the device under test.

A. A minimum of six significant figures must be used in all calculations involving reported constants, masses, etc. The manufacturer's claims for accuracy assume the local gravity to be known to at least six significant figures

B. When the piston pressure gauge is used as a standard of pressure, it is convenient to perform the pressure-to-mass calculations in advance of operating the standard. Since the piston gauge temperature fluctuates while it is operated, a confusing point in the procedure is the necessity for the temperature of the gauge to be predicted prior to operation. This “expected temperature” however is used to allow the pressure calculations to be performed. Once the piston pressure gauge is floating at the intended pressure, a final temperature observation is made and then “trim” masses are loaded onto the piston gauge to correct for any temperature variations that exist between the expected and the actual temperatures. The final column in the worksheet is used to calculate the temperature coefficient, which defines the amount of trim that is required to correct for this temperature change.

   It is usually prudent to select an expected temperature (t), which is lower than any temperature that will be experienced. This is so that the operator can always add mass to correct for the actual temperature. Adding mass is generally more convenient than subtracting mass from the planned loading arrangement. Standard metric trim mass set is entirely suitable for this purpose.

All of the calculations will be performed to this expected temperature (t). A final trim would be calculated to adjust the piston gauge to the temperature of the piston at the time of the actual measurement. This correction is calculated in the last column of the worksheet. This column represents the number of grams to be added to the stack of masses for a difference in the actual temperature from the expected temperature, (t). The final trim is computed using the following formula and loaded onto the piston gauge;

$$"Temp.\ Coef." \ x \ \left(actual\ temperature - \exp ected\ temperature\right)"$$

The Symbol $A_{o(t)}$ represents the effective area of the piston and its cylinder at atmospheric pressure, when operating at temperature (t); it is obtained from the relation

$$A_{o(t)} = A_{o(23)} \left(1 + c\ \Delta t\right)$$

where:

$A_{o(23)}$	=	reported area of the piston at 23 degrees Celsius
c	=	thermal coefficient of superficial expansion
Δt	=	$\left(t - 23\right)$

C. Gravity and Buoyancy Correction: When the masses are applied to the piston in the presence of the buoyant atmosphere, buoyancy corrections are necessary and are combined with gravity corrections. For convenience, the combined correction K_1 (or K_2) is applied as a multiplier with the result indicating the quantity of apparent mass that is required to produce the desired force (F) on the piston.

For English Units

$$K_1 = (g_s / g_1)\,[\rho_{am} / (\rho_{am} - \rho_{air})]$$

where:

g_s	=	acceleration due to standard gravity, 980.665 cm/sec^2
g_1	=	acceleration due to local gravity in cm/sec^2
ρ_{air}	=	density of air in g/cm^3; see Equation A-4
ρ_{am}	=	density of apparent mass;
		for Apparent Mass versus Brass, 8.4 g/cm^3
		for Apparent Mass versus Stainless Steel, 8.0 g/cm^3

When selecting masses from the calibration report, assure that the values selected are in the same Apparent Mass unit of measure that was used to calculate the K_1 or K_2 values.

The apparent mass (Column 9) is obtained from:

$$M_A = F\ K_1$$

where:

M_A	=	apparent mass; record in Column 9
F	=	force required on piston; as found in Column 8
K_1	=	multiplier which was determined by previous equation

For SI Units:

$$K_2 = 1/\left[g_1\left(1 - \rho_a / \rho_b\right)\right]$$

where:

g_1	=	acceleration due to local gravity in m/sec^2
ρ_{air}	=	density of air in g/cm^3; see Equation A-4
ρ_{am}	=	density of apparent mass;
		for Apparent Mass versus Brass, 8.4 g/cm^3
		for Apparent Mass versus Stainless Steel, 8.0 g/cm^3

When selecting masses from the calibration report, assure that the values selected are in the same Apparent Mass unit of measure that was used to calculate the K_1 or K_2 values.

The apparent mass (Column 9) is obtained from:

$$M_A = F\,K_2$$

where:

M_A	=	apparent mass versus brass; record in Column 9
F	=	force required on piston; as found in Column 8
K_2	=	multiplier which was obtained by previous equation

When the masses are applied to the piston in an evacuated bell jar, the above equations for K_1 and K_2 can still be used. In this situation, the density of air (ρ_{air}) will be zero which will cause the buoyancy portion of the equation to become 1. Also, the results will indicate the quantity of true mass (not apparent mass) that must be applied to the piston.

D. Column 1, P_b, is the desired pressure at the reference plane of the device being calibrated.

E. Column 2 is the mass density of the pressure medium being used in the piston pressure gauge system. For hydraulic piston pressure gauges, this number can be considered constant for all pressures. RUSKA Instrument has two types of hydraulic piston fluids available. One is a Spinesstic 22™ part number 55-500 which has a density of 0.031 pounds per cubic inch (858 kilograms per cubic meter). The other is a Dioctyl Sebacate (DOS) part number 55-521-1 which has a density of 0.033 pounds per cubic inch (913 kilograms per cubic meter). For gas medium piston gauges, the values in Column 2 will be different for different system pressures. Equations are provided to calculate the density of air or nitrogen as a function of the system pressure.

F. Column 3 is required to adjust the mass density of the pressure medium for local gravity. It is also used to correct the pressure head that exist between the reference ports of the piston gauge and device under test.

G. Column 4, P_H , is the pressure correction that is required if the reference plane of the device being calibrated is not the same plane as the reference plane of the piston pressure gauge. The difference between the two planes, h, is positive if the reference plane of the device being calibrated is higher than the reference plane of the piston pressure gauge.

H. Column 5 is the pressure required at the reference plane of the piston pressure gauge to produce the desired pressure at the reference plane of the device being calibrated. When the piston gauge is operating in the absolute mode, the Reference pressure, P_R, is subtracted to obtain the differential pressure that the piston is required to generate.

I. The value of $1 + b_1 P_A + b_2 P_A^{\ 2}$, which is used to determine the piston area at different system pressures, is recorded in column 6. For some pistons, b_1 and/or b_2 are equal to zero. Always observe the sign in front of b_1 and b_2 as found in the calibration report.

J. Column 7 is used to record $A_{e(t)}$ which is the area of the piston at pressure P_A and at the expected temperature (t).

K. Column 8, the weight load, is the force required on a piston of given area to produce a given pressure

$$F = P_A A_{e(t)}$$

where:

F	=	Weight load or force on the piston
P_A	=	Pressure as indicated in Column 5
$A_{e(t)}$	=	Effective piston area at the expected temperature (t).

M. Column 9 is the apparent mass that is required to produce the force listed in Column 8.

N. Column 10 is a listing of the different masses to be loaded on the piston pressure gauge to create the pressure listed in Column 5. The masses which will be listed here are in addition to the **tare** components (piston, surface tension effects, bell jar reference pressure, etc.). The mass of the tare components must be subtracted from the mass shown in Column 9 before selection of the miscellaneous masses is started.

After subtracting the TARE mass from the Total Mass shown in Column 9, we must now subdivide/distribute the remaining required mass value among the available masses that will be loaded onto the Piston Table Assembly. It is most likely that there may be many combinations of available masses that could be used to yield the required Total Mass. However, it is strongly recommended that an orderly and sequential method by used. From the Mass Set Table (calibration report) first determine if the Sleeve Mass is required (which would be the case if the realization of the Total Mass value would require the use of the larger platter masses). If yes, then subtract its mass value from the Total Mass value which results in a new "remainder". From this "remainder" mass value, choose the next largest available mass value that may be subtracted. If the choice is from one of several "nominal" mass platters then choose the first one in the available sequence. Subtract this value from the "remainder", which now results in another new "remainder" mass value.

Continue this process until the "remainder", which now results in another new "remainder" mass value. Continue this process until the "remainder" is smaller than the smallest available mass from the mass set. At every step record the selected mass (its mass ID number) into Column 10.

O. Column 11, the remainder from Column 10, is the mass that must be placed on the piston pressure gauge to complete the mass needed to set the desired pressure. This "remainder", recorded in Column 11, is realized with the Trim Mass set provided with all RUSKA Mass Sets. The RUSKA supplied Trim Mass Sets are defined as Class 3, Type 1 (per ASTM E617, formerly Class S1 per NBS Cir. 547).

These fractional masses should also be used to adjust the mass load for piston pressure gauge operating temperatures that differ from the expected temperature (t). These fractional masses could also be used to adjust the mass load for the piston pressure gauge if the reference plane of the device being calibrated is at a different elevation than planned in the original head correction.

P. In the English system, the remainder can be recorded in pounds in Column 11, and in grams in Column 12. The conversion factor to convert pound mass to grams is 453.59237 g/lbm.

Q. Column 13 is used to calculate a temperature coefficient. This temperature coefficient is used to correct for any piston temperature variation from the expected temperature value that was used to calculate the mass loads for the various pressure points in the worksheet. See item B above.

Equation A-4 - Air Density

Air Density (P_{AIR}) in units of g/cm^3, is calculated as follows;

$$\rho_{air} = \left(0.0004646\ x\ \left(P - 4990221.6\ x\ U\ \ x\ e^{(-5315.56/(273.15\ +\ t))}\right)\right) / \left(273.15 + t\right)$$

where:

P = Barometric Pressure, (mmHg)

t = Air Temperature, (ºC)

U = Relative Humidity, (%RH)

Nitrogen Density - English Units (0 to 1000 PSIG)

To calculate the density of Nitrogen at pressures from 0 psig to 1000 psig, use the following equation;

$$DENSITY\left(lbm/in^3\right) = \left(2.826\ \ x\ 10^{-6}\right)\ x\ P$$

where;

$P = PRESSURE$ in psi absolute (if P is in gauge, convert it to an absolute value by adding barometric pressure, e.g. $P + 14.7$)

Nitrogen Density - English Units (1,000 to 15,000 PSIG)

To calculate the density of Nitrogen at pressures from 1,000 psig to 15,000, use the following equation;

$$DENSITY\left(lbm/in^3\right) = \left(2.37465\ \ x\ 10^{-4}\right) + \left(2.74396\ 10^{-6}\right)P - \left(9.46069\ \ x\ 10^{-11}\right)P_2$$

where;

$P = PRESSURE$ in psi absolute (if P is in gauge, convert it to an absolute value by adding barometric pressure, e.g. $P + 14.7$)

Nitrogen Density - SI Units (0 to 6.9 MPa)

To calculate the density of Nitrogen at pressures from 0.01 MPa gauge to 6.9 MPa, use the following equation;

$$DENSITY\left(kg/m^3\right) = \left(1.1347\ \ E - 05\right)\ x\ P$$

where;

$P = PRESSURE$ in Pa absolute (if P is in gauge, convert it to Pa absolute by adding barometric pressure, e.g. $\mathrm{P} + 101325$)

Nitrogen Density - SI Units (6.9 MPa to 100 MPa)

To calculate the density of Nitrogen at pressures from 6.9 MPa gauge to 100 MPa, use the following equation;

$$DENSITY\left(kg/m^3\right) = 6.573 + (11.016)P - (0.055087)P^2$$

where;

$P = PRESSURE$ in MPa absolute (if P is in gauge, convert it to MPa absolute by adding barometric pressure, e.g. $\mathrm{P} + 101325$)

Zero Air Density - SI Units (0 MPa to 20.7 MPa)

To calculate the density of Zero Air at pressures to 20.7 MPa, use the following equation;

$$DESNSITY\left(kg/m^3\right) = \left(1.17\ \ E - 05\right)\ x\ P$$

where;

$P = PRESSURE$ in Pa absolute (if P is in gauge, convert it to Pa absolute by adding barometric pressure, e.g. $\mathrm{P} + 101325$)

Helium Density - SI Units (0 to 6.9 MPa)

To calculate the density of Nitrogen at pressures from 0.01 MPa gauge to 6.9 MPa, use the following equation;

$$DENSITY\left(kg/m^3\right) = \left(1.585\ \ E - 06\right)\ x\ P$$

where;

$P = PRESSURE$ in Pa absolute (if P is in gauge, convert it to Pa absolute by adding barometric pressure, e.g. $\mathrm{P} + 101325$)

Helium Density - SI Units (6.9 MPa to 100 MPa)

To calculate the density of Nitrogen at pressures from 6.9 MPa gauge to 100 MPa, use the following equation;

$$DENSITY\left(kg/m^3\right) = 0.3136\ \ E - 01 + (1.508)P - \left(3.886\ \ E - 03\right)P^2$$

where;

$P = PRESSURE$ in MPa absolute (if P is in gauge, convert it to MPa absolute by adding barometric pressure, e.g. $P + 0.101325$)

Conversion Factors

Table A-1. Conversion Factors

To Convert From	To	Multiply By
Pa	N/m^2	1
N/m^2	Pa	1
Pa	MPa	10^{-6}
MPa	Pa	10^{-6}
N/m^2	MPa	10^{-6}
MPa	N/m^2	10^{-6}
Pa	PSI	1.450377×10^{-4}
PSI	Pa	6894.76
MPa	PSI	145.0377
PSI	MPa	6.89476×10^{-3}

Where: Pa = pascal

MPa = megapascal

N = newton

M = meter

PSI = pounds per square inch

PISTON PRESSURE GAUGE PRESSURE CALCULATION WORKSHEET (ENGLISH UNITS)

Date	________		Expected Temperature, (t)	________	°C		
Reference Plane Difference, h	________	inch	$A_{o(t)} = A_{o(23)}[1 + c(t-23\ ^{o}C)]$	________	$inch^2$		
Mass Set Serial No.	________		Local Gravity, g_L	________	cm/sec^2		
Piston Serial No.	________		Air Density, ρ_{air}	________	g/cm^3	________	lb/in^3
$A_{o(23)} = A_o$ at 23 °C	________	$inch^2$	Gravity & Buoyancy, K_1	________			
b_1	________	/psi	Tare, Apparent Mass	________	pound		
b_2	________	$/psi^2$	Reference Pressure, P_R	________	mtorr	________	psi
c	________	/ °C					

1	2	3	4	5	6	7	8	9	10	11	12	13
P_B NOMINAL PRESSURE	ρ_{medium} (Mass Density)	$\rho_W = (\rho_{medium} - \rho_{air}$ lb/in^3) $\times g_L \div 980.665$	$P_H = \rho_W \times h$	$P_A = P_B + P_H - P_R$	$1 + b_1 P_A + b_2 P_A^2$	$A_{e(t)} = A_{o(t)} \times$ Column 6	$F = P_A \times A_{e(t)}$	$M = F \times K_1$	Masses to be used	Remainder	Remainder	Temp. Coef. = Column 9 x 453.59237 x c
psi	lb mass/in^3	Lb force/in^3	psi	psi		in^2	lb force	lb mass	**Tare** Plus	lb mass	grams	g/°C

PISTON PRESSURE GAUGE PRESSURE CALCULATION WORKSHEET (SI UNITS)

Date ______________

Reference Plane Difference, h ______________ m

Mass Set Serial No. ______________

Piston Serial No. ______________

$A_{o(23)} = A_o$ at 23 °C ______________ m^2

b_1 ______________ /MPa ______________ /Pa

b_2 ______________ $/Mpa^2$ ______________ $/Pa^2$

c ______________ / °C

Expected Temperature, (t) ______________ °C

$A_{o(t)} = A_{o(23)}[1 + c(t-23\,^{\circ}C)]$ ______________ m^2

Local Gravity, g_L ______________ m/sec^2

Air Density, ρ_{air} ______________ g/cm^3 ______________ kg/m^3

Gravity & Buoyancy, K_2 ______________

Tare, Mass ______________ kg

Reference Pressure, P_R ______________ mtorr ______________ Pa

1	2	3	4	5	6	7	8	9	10	11	12
P_B NOMINAL PRESSURE	ρ_{medium} (Mass Density)	$\rho_W = (\rho_{medium} - \rho_{air}\ kg/m^3) \times g_L$	$P_H = \rho_W \times h$	$P_A = P_B + P_H - P_R$	$1 + b_1P_A + b_2 P_A^2$	$A_{e(t)} = A_{o(t)} \times$ Column 6	$F = P_A \times A_{e(t)}$	$M = F \times K_2$	Masses to be used	Remainder	Temp. Coef. = Column 9 x 1000g/kg x c
Pa	kg/m^3	N/m^3	Pa	Pa		m^2	N	kg	**Tare** Plus	grams	g/°C

Appendix B
Setup Kit Bills of Material

Setup Kit 2485-202 for RUSKA 2485-930/950

Table B-1. Setup Kit 2485-202 for RUSKA 2485-930/950

Part Number	Description	Qty & Unit of measure	Notes
2411-702-010	RTD (PRT) HOLDER 1/8 NPT X 3/16"	1.00 EACH	
2465-100	PISTON & CYLINDER CLEANING KIT	1.00 EACH	
2485-102-001	LOW RANGE CYLINDER CLEANING TOOL	1.00 EACH	
2485-1D02	USER'S MANUAL	1.00 EACH	
2485-920	MIRROR BLOCK	1.00 EACH	FOR FLOAT POSITION
2485-KIT-001	ADAPTER KIT	1.00 EACH	FOR AUXILIARY CONNECTOR BLOCK
26-216	FUSE, 1 AMP, SLOW BLOW (SIZE 3AB)	2.00 EACH	
54-700-437	DRIVE BELT, 2485	1.00 EACH	FOR ROTATION SLEEVE
54-703-008	O-RING, VITON, 3/16 I.D. X 1/16 CROSS SECTION	6.00 EACH	FOR EXTENDED RANGE P/C
54-703-117	O-RING VITON 13/16 X 3/32 CROSS SECTION	2.00 EACH	FOR P/Cs OTHER THAN EXTENDED RANGE
54-703-14	O-RING, VITON, 1/2 I.D. X 1/16 CROSS SECTION	6.00 EACH	FOR EXTENDED RANGE P/C
72-33	SEAL, 1/4 X 1/2 PLOYPAK	4.00 EACH	FOR CONNECTOR BLOCK
86-802	TUBING, CLEAR PLASTIC, 3/8 OD X 1/16 W X 1/4 ID	5.00 FEET	WASTE MEDIA DRAIN LINE
94-607	WRENCH, HEX KEY, 1/8	1.00 EACH	
94-608	WRENCH, HEX KEY, 3/32	1.00 EACH	

Table B-2. Setup Kit 2485-202 for RUSKA 2485-930/950, continued.

Part Number	Description	Qty & Unit of Measure	Notes
94-617	WRENCH: PIN SPANNER 2" DIAMETER W/ 1/4 PIN	1.00 EACH	
94-618	WRENCH: PIN SPANNER, 2.25" DIAMETER W/ 1/4 PIN	1.00 EACH	
94-628	WRENCH, OPEN END, 1/4 X 5/16"	1.00 EACH	
94-629	WRENCH, OPEN END 5/8" X 11/16"	1.00 EACH	
94-632	WRENCH, OPEN END 1/2 X 9/16	1.00 EACH	
94-637	WRENCH, OPEN END 7/16" X 1/2"	1.00 EACH	
94-664	WRENCH, ADJUSTABLE 12"	1.00 EACH	
94-686	WRENCH, OPEN END 3/4" X 7/8"	1.00 EACH	
99189	RUSKA GLOVES	1.00 PAIR	FOR HANDLING MASSES

Table B-3. Setup Kit 2485-203 for RUSKA 2485-935

Part Number	Description	Qty & Unit of Measure	Notes
2411-702-010	RTD (PRT) HOLDER 1/8 NPT X 3/16"	1.00 EACH	
2465-100	PISTON & CYLINDER CLEANING KIT	1.00 EACH	
2485-102-001	LOW RANGE CYLINDER CLEANING TOOL	1.00 EACH	
2485-1D02	USER'S MANUAL	1.00 EACH	
2485-203-001	GLAND REMOVAL TOOL	1.00 EACH	FOR PRESSURE COLUMN
2485-203-002	P/C ASSEMBLY TOOL	1.00 EACH	FOR QUICK-CHANGE P/C HOLDER
2485-920	MIRROR BLOCK	1.00 EACH	
2485-935-007	BACKUP RING	1.00 EACH	FOR PRESSURE COLUMN
2485-KIT-001	ADAPTER KIT	1.00 EACH	FOR AUXILIARY CONNECTOR BLOCK
26-216	FUSE, 1 AMP, SLOW BLOW (SIZE 3AB)	2.00 EACH	
54-603-008	O-RING, VITON 3/16 I.D. X 1/16 CROSS SECTION, 60 DUROMETER	10.00 EACH	FOR 40 K PSI P/C
54-700-437	DRIVE BELT, 2485	1.00 EACH	FOR ROTATION SLEEVE
54-703-117	O-RING VITON 13/16 X 3/32 CROSS SECTION	2.00 EACH	FOR P/Cs OTHER THAN 40 KPSI
72-33	SEAL, 1/4 X 1/2 POLYPAK	4.00 EACH	FOR CONNECTOR BLOCK

Table B-4. Setup Kit 2485-203 for RUSKA 2485-935, continued.

Part Number	Description	Qty & Unit of Measure	Notes
72-43	SEAL .625 OD X .375 ID POLYPAK	4.00 EACH	FOR HAND PUMP AND COLUMN
86-802	TUBING, CLEAR PLASTIC, 3/8 OD X 1/16 W X 1/4 ID	5.00 FT	WASTE MEDIA DRAIN LINE
91-398	DISK SPRING WASHER .505 X 1.0	2.00 EACH	FOR 40K QCPC HOLDER
94-607	WRENCH, HEX KEY, 1/8	1.00 EACH	
94-608	WRENCH, HEX KEY, 3/32	1.00 EACH	
94-617	WRENCH: PIN SPANNER 2" DIAMETER W/ 1/4 PIN	1.00 EACH	
94-618	WRENCH: PIN SPANNER, 2.25" DIAMETER W/ 1/4 PIN	1.00 EACH	
94-628	WRENCH, OPEN END, 1/4 X 5/16"	1.00 EACH	
94-629	WRENCH, OPEN END 5/8" X 11/16"	1.00 EACH	
94-632	WRENCH, OPEN END 1/2 X 9/16	1.00 EACH	
94-637	WRENCH, OPEN END 7/16" X 1/2"	1.00 EACH	
94-664	WRENCH, ADJUSTABLE 12"	1.00 EACH	
94-686	WRENCH, OPEN END 3/4" X 7/8"	1.00 EACH	
99189	RUSKA GLOVES	1.00 PAIR	FOR HANDLING MASSES
99199-008	PIN WRENCH, STRAIGHT, 1/4"	1.00 EACH	