RUSKA INSTRUMENT CORPORATION ✥ HOUSTON, TEXAS

MODEL 2480/2481

PISTON PRESSURE GAGE

OPERATING INSTRUCTIONS

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MODEL 2480 AND 2481

PRESSURE STANDARD

W A R N I N G

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 INNOCENT SPECTATORS, AND TO THE EQUIPMENT.

SECTION I

INSTALLATION

INSTALLATION

Remove the instrument from the shipping box and place it in position on a solid working surface with each foot in a foot plate. Connect the instrument to the pressurizing source and to the test instrument with tubing and components which have the required working pressure rating.

This system should be installed in an air-conditioned room away from heavy personnel traffic and air drafts. The environment should be controlled for personnel comfort only; very close control of the ambient temperature is unnecessary, since rather large temperature changes will occur within the system during operation. Operating procedures will accomodate the temperatures encountered. Airborne dust is undesirable, but clean-room standards in the control of quantity and size of dust particles are not required. A conditioned atmosphere of commercial quality is adequate. An auxiliary table nearby will be convenient for temporary placement of weights, tools, and work pieces while operating the system.

SECTION II

SPECIFICATIONS AND CALIBRATION REPORTS

DESCRIPTION OF THE RUSKA MODEL 2480/2481 DEAD WEIGHT GAGE

The Ruska Model 2480/2481 Dead Weight Gage was designed as a laboratory reference of pressure.

High operating range and mechanical durability are features that have been made possible by the use of a secondary piston of relatively large diameter. With this arrangement, the measuring piston may be made small in area without the hazard of damage from accidental misuse. A measuring piston whose area is small permits measurement of rather high pressures with weights of the size that may be conveniently handled by one person.

A circular table (termed "WEIGHT TABLE"), on which the weights are placed, is attached to the secondary piston (TABLE SUPPORT).

Referring to the accompanying cross sectional diagram Figure 1-1. The TABLE SUPPORT rests directly on the MEASURING PISTON THRUST PLATE and is guided axially by the TABLE SUPPORT BUSHING.

Overranging load protection is accomplished by the use of an arrangement of ball THRUST BEARINGS located above the guide bushing. The gage may be safely operated with a full load of weights and with no pressure, or it may be fully pressuirzed without weights. The arrangement satisfies the condition necessary for performing hysteresis measurements in which the selected pressures are approached from below and above without appreciable overpressure.

The combined weight of the WEIGHT TABLE assembly and piston assembly constitutes the tare weight of the gage. When the tare weight is divided by the effective area of the piston, the quotient is the tare pressure--the minimum pressure which the gage is capable of measuring and a pressure which is a part of every measurement made with the gage.

The cylinder is of re-entrant design and operates over the entire range of pressures without excessive leakage.

The Model 2480/2481 gage is provided with a post carrying an index line which indicates a particular floating position of the piston. This position is usually near the center of the total displacement. The position of the pressure reference plane for each piston is reported with respect to the top surface of the weight table. A line is cut in the periphery of the sleeve weight platter (No. 1 Weight) which, when placed in alignment with that of the index post, indicates the correct piston floating position. The true location of the pressure reference plane is determined by subtracting the distance shown on the test report from the dimension of the sleeve weight corresponding to the vertical distance from the peripheral line to the internal surface that rests on the weight table.

A second index line is located on the knurled cap and weight table drive pin. When the pressure on the dead-weight gage is less than that requiring the sleeve weight, the position of the piston is determined by the second index mark.

The pressure at any point in the system may be determined by measuring the vertical distance of the point from the reference plane of the dead-weight gage. The pressure at the point, in psi, will be the vertical distance from the pressure reference plane, in inches, multiplied by the density of the oil in pounds per cubic inch.

When the piston gage is used as a standard of pressure for calibration of secondary pressure sensors, integral values of pressure are precalculated to the extent possible. These pressures are valid only at the pressure reference plane of the piston. A procedure for transferring these integral values to other positions within the system is described in Section IV of this manual.

DESCRIPTION OF THE WEIGHTS

All weights are constructed of Type 303 stainless steel. They are entirely machined from rolled stock or forgings, and the removal of any metal is performed in such a way as to maintain balance about the centerline. Final adjustment is accomplished by drilling a symmetrical pattern of holes concentric with the axis.

INSTALLATION OF THE GAGE

The dead weight gage must be erected on a pier or heavy table. The two leveling screws and the leg at the rear of the base casting are supported by the foot plates furnished with the instrument. The gage must be leveled and the leveling screws locked.

UNITS

The test reports and statements of accuracy are generated by computer through a time-share terminal. As a result, superscripts and subscripts of units are not available. Also, the standard form of scientific notation (with exponents for powers of 10) is not available.

Listed below are those units in question plus a definition of the same.

IN2	;	Square Inch
CM2	;	Square Centimeter
CM3	;	Cubic Centimeter
9.1 E-05	;	9.1×10^{-5}
AO	;	Effective Area at Zero Pressure
M	;	Meter
M2	;	Square Meter
PA	;	Pascal (Newton/Square Meter)
MPA	;	Mega Pascal (Pascal x 10)

SECTION III

OPERATION CONSIDERATIONS

TYPES OF PISTON PRESSURE GAGES

The Dead Weight Tester or pressure balance 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 dead weight testers qualify in this category.

Figures 3.1, 3.2 and 3.3 illustrate the three most common type of cylinder arrangements.

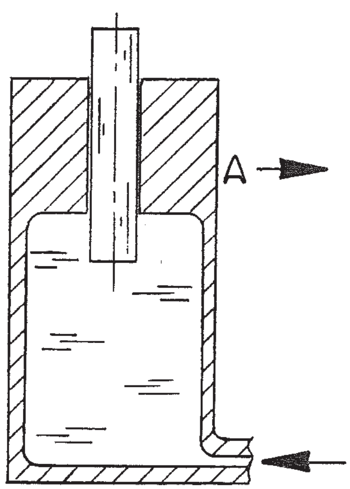

FIGURE 3.1

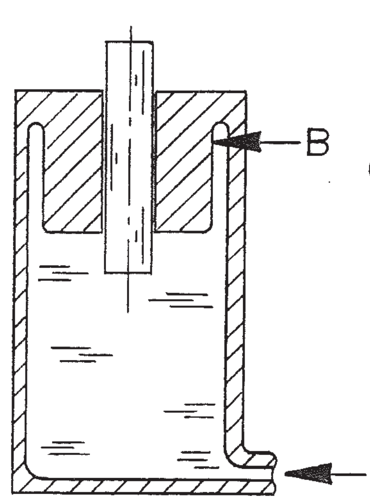

FIGURE 3.2

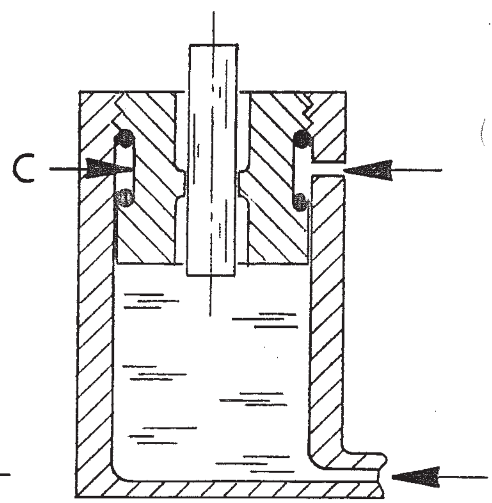

FIGURE 3.3

When the simple cylinder of Figure 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 and thus increases its area. A pressure-drop appears across the cylinder wall near the point A and results in an elastic dilation of the cylinder bore.

It can be shown that the effective area of the piston and cylinder assembly is the mean of the individual areas of the piston and of the cylinder; therefore, as the pressure is increased, the cylinder expands and the effective area becomes greater. The rate of increase is usually but not always a linear function of the applied pressure. The piston also suffers distortion from the end-loading effects and from the pressure of the fluid but to a much less extent than the cylinder. It is evident, then, that the simple cylinder of Figure 3.1 would be inadequate for a primary dead weight tester unless some 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 at some pressures that insufficient floating time can be maintained for a proper pressure measurement.

In Figure 3.2, 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 1. In consequence, the elastic distortion is directed toward the piston, tending to decease the area of the cylinder.

Again, the change in area with changing pressure places a limit on the usefulness of cylinder No. 3.2 as a primary instrument. But some benefit results from the use of cylinder No. 3.2 in the construction of a dead weight tester 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 must necessarily be greater at low pressure for cylinder No. 3.2 than for cylinder No. 3.1.

In the controlled-clearance design of Figure 3.3, the cylinder is surrounded by a jacket to which a secondary fluid pressure system is connected. Adjustment of the secondary, or jacket, 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. In the United States, the controlled-clearance piston gage is the accepted standard of pressure at levels higher than those that are practical for the mercury manometer.

Piston gages having very high resolutions may be made by using simple and re-entrant cylinders. A determination of the distortion coefficients of such gages may be made by direct comparison with a controlled-clearance gage. Most piston gages have some elastic distortion, but some, used in the very low pressures, have only small coefficients and, in some instances, correction for distortion may be neglected.

Measurement of pressure with the piston gage is subject to uncertainties resulting from effects other than those of elastic distortion. It is appropriate that the subject of elastic distortion be discussed first, since this characteristic is largely responsible for the various designs that have been developed.

Measurement processes proposed for high accuracy are disturbed by limitations in the performance of the equipment, by small changes in the environment and by operational procedures. The disturbances can be reduced to a degree by exercising control of the environment and development of skill in the operation of the apparatus. Some of the disturbances are difficult to control; it is easier to observe their magnitudes and apply corrections for their effects.

The factors that disturb a pressure measurement process when conducted with a piston pressure gage are described below. It is important that the operator acquaint himself with these factors and become accustomed to recognizing their presence. The success of the measurement will depend upon the degree to which control has been maintained or to the completeness by which corrections were applied for the disturbances.

Factors Affecting the Performance of the Piston Gage and the Measurement Process

Elastic Distortions of the piston and cylinder.

Temperature of the piston and cylinder.

Effects of gravity on the masses.

Buoyant effect of the atmosphere upon the masses.

Hydraulic and gaseous pressure gradients within the apparatus.

Surface tension effects of the liquids.

THE MEASUREMENT OF PRESSURE WITH THE PISTON GAGE

Pressure results from the application of a force which is distributed over an area of surface; it is defined as a force or thrust exerted over a surface divided by its area.

$$P = \frac{F}{A}$$ where

P represents the pressure, F the force, and A the area.

Elastic Distortion of the Cylinder--

As the pressure is increased within a piston gage, the re- resulting stress produces a temporary deformation of the cylinder. The net effect is a change in the effectyive area of the piston. If the change in the area is a linear functions of the applied pressure, the relationship may be described by the equality

$$A_e = A_o(1 + bp)$$ where

A_e is the effective area at a pressure, p,

A_o is the area of the piston-cylinder assembly as a reference pressure level, and, b, a coefficient of elastic distortion that is determined experimentally. The value of b is the fractional change in area per unit of pressure.

TEMPERATURE

Dead Weight Gages are temperature sensitive and must, therefore, be corrected to a common temperature datum.

Variations in the indicated pressure resulting from changes in temperature arise from the expected change in effective area of the piston. Treatment, therefore, is a straightforward application of the thermal coefficients of the materials of the piston and cylinder. By substituting the difference in working temperature from the reference temperature and the thermal coefficient of area expansion in the relation

$$A_o\ (t) = A_o\ (\text{Ref. } t)\ (1 + C\ \Delta t)$$

the area corresponding the the new temperature may be found.

In the equation above,

A_o (t) = Area corrected to the working temperature.

A_o (Ref. t) = Area of the piston at zero PSIG and at the selected reference temperature.

C = Coefficient of superficial expansion as indicated in the test report.

Δt = Difference between working temperature and reference temperature.

The magnitude of error resulting from a temperature change of 5° C for a tungsten carbide piston in an alloy-steel cylinder is approximately .008%.

For work of high precision, gage temperatures are read to the nearest 0.1°C.

THE EFFECTS OF GRAVITY

The confusion and ambiguity that has resulted from the carelessness with which the terms mass, weight, and force have been used is under severe and just attack by those who recognize the consequences in the continuation of such practice (see reference 8). The scientific community has long been careful in the use of terms involving units and dimensions. We are obligated to pay attention to what they have to say. We are at the threshold of international agreement on a unified system of weights and measures. It is important that, regardless of how inconvenient or mysterious these new units appear to us, we must quickly become acquainted with them and contribute our best effort toward a rapid and successful transition to the new system. The new units and their definitions leave little room for ambiquity. An understanding of the relationship between units of the International System will help us in correcting our habits with the use of our present units.

Objects familiar to us are attracted toward the earth by the action of gravity. We are interested in this attraction because it provides a way in which we can apply accurately-determined forces to the piston of a pressure gage. The force may be evaluated if we know the mass of the object to be placed on the gage piston. The quantity is expressed as

$$F = k\,Mg_\ell \quad \text{(See Reference 2)}$$

Where $g\ell$ is the local acceleration due to gravity, M the mass of the object, and k a constant whose value depends upon the units of F, M, and $g\ell$:

k = 1 for F in Newtons, M in kilograms, and $g\ell$ in Meters/Sec^2.

k = $\frac{1}{980.665}$ for F in kilograms force, M in kilograms, $g\ell$ in cm/sec^2.

k = $\frac{1}{980.665}$ for F in pounds force, M in pounds mass, and $g\ell$ in cm/sec^2.

BUOYANT EFFECT OF THE AIR

According to Archimede's principle, the weight of a body in a fluid is diminished by an amount equal to the weight of the fluid displaced. The weight of an object (in air) that has had its mass corrected for the effects of local gravity is actually less than the corrected value indicates. The reduction in weight is equal to the weight of the quantity of air displaced by the object or the volume of the object multiplied by the density of the air. But the volume of an irregular shaped object is difficult to compute from direct measurement. Buoyancy corrections are usually made by using the density of the material from which the object is made. If the value of mass is reported in units of apparent mass vs brass standards rather than of true mass, the density of the brass standards must be used. Apparent mass is described as the value the mass appears to have as determined in air having a density of 0.0012 g/mℓ, against brass standards of a density of 8.4 g/cm^3, whose coefficient of cubical expansion is 5.4 x 10^{-5}/ $^{\circ}$C, and whose value is based on true mass in value (see reference 4).

Although the trend is swinging toward the use of true mass in favor of apparent mass, there is a small advantage in the use of the latter. When making calculations for air buoyancy from values of apparent mass, it is unnecessary to know the density of the mass. If objects of different densities are included in the calculation, it is not necessary to distinguish the difference in the calculations. This advantage is obtained at a small sacrifice in accuracy and is probably not justified when considering the confusion that is likely to occur if it becomes necessary to alternate in the use of the two systems.

A satisfactory approximation of the force on a piston that is produced by the load is given by

$$F = M_a \quad 1 - \frac{\rho a}{\rho a} \quad k \quad g\ell$$

Where:

F = the force on the piston

M_a = Mass of the load, reported as "apparent mass vs brass standards"

ρa = Density of the air.

ρb = Dessity of brass (8.4 g/cm^3)

REFERENCE PLANE OF MEASUREMENT

The measurement of pressure is strangly linked to gravitational effects on the medium. Whether in a system containing a gas or a liquid, gravitational forces produce pressure gradients that are significant and must be evaluated. Fluid pressure gradients and buoyant forces on the piston of a pressure balance require the assignment of a definite position at which the relation $P = \frac{F}{A}$ exists. It is common practice to assocaate this position directly with the piston as the datum to which all measurements made with the piston are referenced. It is called the reference plane of measurement and its location is determined from the dimensions of the piston. If the submerged portion of the piston is of uniform cross section, the reference plane is found to lie conveniently at the lower extremity. If, however, the portion of the piston submerged is not uniform, the reference plane is chosen at a point where the piston, with its volume unchanged, would terminate if its diameter were uniform.

When a pressure for the dead weight gage is calculated, the value obtained is valid at the reference plane. The pressure at any other plane in the system may be obtained by multiplying the distance of the other plane from the reference plane by the pressure gradient and adding (or subtracting) this value to that observed at the piston reference plane.

For good work, a pressure gage should be provided with a fiducial mark for associating the reference of the piston with other planes of interest within a system. Not only does the mark serve to establish fixed values of pressure differences through a system, but it indicates a position of the piston with respect ot the cylinder at which calibration and subsequent use should be conducted. If the piston is tapered, it is important to maintain a uniform float position for both calibration and use.

In normal operation, the system is pressurized until the piston is in a floating position slightly above the fiducial or index mark. After a short period, the piston and its load will sink to the line at which time the conditions within the system are stable. If there is a question as to the error that may be produced by accepting a float position that is too high or too low, the error will be equivalent to a fluid head of the same height as the error in the float position. This statement assumes, of course, that the piston is uniform in area over this length.

EFFECTS OF LIQUID SURFACE TENSION

One of the smaller disturbances that affect the performance of a piston gage is that resulting from the surface tension of the liquid. The strong meniscus that is formed around the piston as it enters the cylinder is visible evidence of a force acting on the surfaces. Numerically, the force on the piston that results from surface tension is

$$F_{st} = \gamma C$$

where

γ = Surface tension of the liquid in dynes/cm or pounds force/in.

C = Circumference of piston in centimeters or inches.

CONDITIONS FAVORABLE FOR A MEASUREMENT

THE BEGINNING--DETERMINATION OF THE ZERO PRESSURE.

A pressure measurement is no better than its beginning. All pressure measurements are made with respect to something. When a value of pressure is expressed, it is implied that the difference between two pressure levels is the value stated. In order to determine the difference between two pressures, each of the pressures must be measured. Furthermore, if a level of confidence is stipulated for the expressed value of pressure, the confidence figure must include the errors of each of the pressure measurements. This problem is not unique to pressure measurement and is brought to attention here to impress, by repetition, the importance of proper zero measurement at the start.

Errors in establishing a strating-point zero at the beginning of the test arise principally from uncertain oil heads in various parts of the equipment. In general, the vertical dimensions of a hydraulic calibrating system, such as would normally be connected to a laboratory dead weight gage, are small; therefore, the total head error is relatively small. If the pressure to be measured or generated is large, the small starting error may possibly be neglected. But if pressures in the low ranges are expected to be measured with high accuracies, small head errors at the beginning are quite significant.

When using the piston gage as a standard of pressure for the calibration of elastic-type sensors in the low ranges, the problem of establishing a datum for the sensor is one that requires attention. The sensor usually has a mechanical or electrical adjustment for setting the zero. Some adjustments may have a considerable range which enables the device to indicate zero although a rather large bias may be present at the time the zero is adjusted.

If a pressure reference plane is not stipulated in the documents for the sensor, one must be chosen. The choice may be an arbitrary one or it may be one based on obvious details of sensor geometry. All pressures must be thereafter referenced to this datum.

When calibrating gages or transducers with gas, using a diaphragm barrier between the oil and gas portions of the system, it is necessary that the readout mechanism of the diaphragm device be adjusted to zero when no pressure existed across the diaphragm. The diaphragm terminates the liquid portion of the system, thus it becomes the interface of the oil and gas media. Head corrections are computed for the difference in height of the piston gage reference and interface diaphragm for the oil and from the diaphragm to the transducer for the gas system. If the gas system is opened to atmosphere and the liquid system is also opened at a point of equal height of the diaphragm, the pressure across the diaphragm will be zero and the readout mechanism may be adjusted to zero. After the transducer is also carefully adjusted to zero, the gas system may be closed, and the calibration begun.

One source of error at low pressures is the presence of air in the system. If a quantity of air is present in the verical section of a connecting tube, the assumed head correction will be in error. If air migrates to the dead weight gage, the reference plane may be shifted because the buoyancy of the oil upon the piston has been upset.

A quantitative measurement of the amount of air in the system may be made by taking note of the number of turns necessary on the hand pump handle to raise the bourdon gage pointer a perceptible amount. The dead weight gage must have a weight on piston to make the test effective. When no air exists in the system, the pointer will move almost immediately as the pump handle is rotated slowly.

ESTABLISHING THE PRESSURE

Assuming the dead weight tester is to be used in the calibration of a pressure measuring device, and, assuming also that the device has been properly tested and exercised prior to calibration, the selection of weights is placed on the dead weight tester according to the results of the calculations. The pressure may be raised until the dead weight gage is floating in a rather high position.

For the first few moments, the weights on the dead weight tester may be observed to fall rather rapidly--more so than usual. The unusual descent rate is observed for three or more reasons: (1) the packing of the valves, pump plunger, and O-rings seals is compressible to some extent and reluctant to be squeezed into the packing gland. The movement of the packing is not instantaneous; (2) any air in the system is forced into solution by the increased pressure. Dissolution of the gas causes a reduction in the volume of the pressurized fluids which is manifested by an apparent increase in fall rate; (3) the greatest contribution fo the increased sink rate is the contraction in fluid volume from the transfer of the heat to the apparatus. The increase of pressure is accompanied by a sharp rise in temperature of the oil and also a rather large volume expansion. As the vessels of the system absorb the heat, the oil contracts and thus causes an apparent increase in leakage in the dead weight tester.

The effects of the three causes are additive and serve to indicate an apparent high rate of leakage. The sink rate may be measured with a scale and watch. If measurements are plotted for each minute interval for several minutes, the curve will drop sharply the first few minutes and then level off to a constant value. After raising the pressure to values as high as 600 to 700 atmospheres, seven to eight minutes are required for the thermal effects to die out.

CROSSFLOATING

It was mentioned earlier that some dead weight gages must be calibrated against a standard gage. In the jardon of the laboratory, the process is called crossfloating. When cross-floating one gage against another, the two are connected together and brought to a common balance at various pressures. The balancing operation is identical with that employed on an equal-arm weight balance where the mass of one weight is compared to another. In each instance the operator must decide when the balance is complete. In a crossfloat, the two gages are considered to be in balance when the sink rate of each is normal for that particular pressure. At this condition there is no pressure drop in the connecting line and consequently no movement of the fluid. The condition can be difficult to recognize, particularly if there is no means of amplification in the method of observing. The precision of the comparison will depend directly upon the ability of the operator to judge the degree to which the balance is complete. This procedure is repeated for several pressures and the values of areas obtained are plotted against the nominal pressure for each point. A least-squares line is fitted to the plots as the most probable value of the area at any pressure.

Of the different methods used in amplifying the signals that are generated by the crossfloat process, one is presently in use that is rapid and convenient. An electronic sensor, which indicates the floating position of the piston, is placed beneath the weights of each gage. The output signal form the sensor is processed and fed to an analog meter having a vertical scale, the value of which is adjusted to indicate units of displacement of the piston. Two meters -- one for each instrument -- are placed contiguously for simultaneous viewing. A constant-volume valve, inserted between the gages, supplements the sensors.

Other, less precise, methods of estimating the true balance, include:

a. Optical amplification of the sinking stack of weights of one of the gages while timing the descent with a stop watch and

b. Interposition of a sensitive null-pressure transducer which displays small pressure differences directly.

When using a suitable amplifying device, the scatter in the plotted areas from a good quality piston gage should not exceed one or two parts per million.

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SECTION IV

SETUP AND OPERATION

SOME PRECAUTIONS TO OBSERVE DURING THE OPERATION OF A DEAD WEIGHT GAGE CALIBRATING SYSTEM

Hydraulic or pneumatic pressures should not be admitted to or released from a system by quickly opening or closing a valve. In most instances at least one of the components of the system contains a sensitive measuring element which may be damaged by a sudden change in pressure. For instance, if a dead weight gage is in a floating position and a valve is quickly opened, permitting the pressure to escape rapidly, the gage could possibly be damaged when the weights, fall freely against the lower stop. Indeed, in some instances it is possible to break a measuring piston. The pressure must be reduced by means of the hand pump until the piston mechanism is resting on its thrust bearings, after which a valve may be opened slowly, releasing the remainder of the pressure. A large and sudden change in pressure in the form of a shock may also damage the sensing unit in the Differential Pressure Indicator.

Before various devices are calibrated against a dead weight gage or other pressure reference, there should be pressure tested at a value somewhat greater than the top working pressure if possible. As outlined above, failure of one of these devices on the calibrating bench can result in considerable stress in the calibrating equipment.

When large changes in pressure are made with the dead weight gage, sufficient time must be allowed after the change for various elements of the system to become stabilized to the change in stresses. For very precise measurements, in pressure, a waiting period of 30 minutes may be necessary.

REMOVAL OF AIR FROM THE HYDRAULIC SYSTEM

Satisfactory performance of the hydraulic system may be obtained only when it is free of air. The presence of an air bubble in the vertical section of a measuring path will surely upset the assumed head that forms a part of the measurement. It is important, therefore, that the air be removed from the system. Once the apparatus is free of air, it is relatively easy to maintain that condition. Although an attempt is made to preserve the condition of the original test, some air may be present because of accidental admission or by liberation from solution during shipment. A procedure for removal of the air involves the gas absorption properties of the oil. Some of the traps in the system cannot be vented directly. A bubble will remain lodged in the trap even though a substantial flow of oil in the vicinity can be produced by the pump. Removal of the bubble can be accomplished by forcing the gas into solution and moving the solution out of the system. If the pressure of the liquid is raised to a few hundred atmospheres, the bubble will dissolve. After a slow leak has been created nearby, the pressure is maintained with the pump while the quantity of oil which includes the solution is forced out of the system. When the solution emerges, it frequently produces a spitting sound as the gas is liberated; at other times, the discharge may appear as a whitish foam.

The hand pump, being the source of pressure, must be cleared of air first. The pump also serves for testing the system for residual air. When making the test, the plunger is advanced by one or two revolutions of the turnstile handle while the inlet valve is open. This operation removes the backlash from the spindle nut threads and bearings. The valve is then closed and the handle turned slowly while the operator watches the bourdon tube gage. If air is present in the system, there will be a lag in the indication of pressure as the pump handle is rotated. An acceptable test is one in which the gage pointer moves a perceptible amount for 1/4 turn of the handle.

Usually, most of the air that is present in the pump accumulates in the gage bourdon tube. The C- or helical-shaped tube forms an ideal trap for capture of a bubble. A suitable funnel or flume may be fashioned from a piece of paper and fastened beneath the bleed port with tape. The escaping oil should not be permitted to flow over the gage movement. After pressurizing the pump, the bleed screw is adjusted for a slow leak of approximately 10 to 15 drops per minute.* The pressure is maintained for the full stroke of the plunger, after which the pump is recharged and the test repeated. It is not necessary to reseal the tip screw during recharging. The new

*See "Notes on Operation of High-Pressure Systems".

test should show an improvement but will, in some instances, reach a limit. When this condition occurs, the remaining air is usually trapped in the nipples and valves. The process is repeated for each of the outlet valves.

If the process reaches a limit beyond which no improvement is evident--even though there is still substantial remaining air--the next component may be attacked. At the conclusion of the process, the residual air may be dissolved by pressurizing the entire system and leaving it under pressure for several hours or overnight. The concentrated solutions, in the vicinity of the traps, will diffuse to the extent that, upon release of the pressure, the entire system will be unsaturated. There will be no further libertation of air. During the dwell period, the piston gage will, of course, be isolated.

Residual air in the piston gage is not a problem, because the leaking piston automatically allows the dissolved gas to escape. It is necessary only to pressurize the gage and allow it to operate for a period before beginning a measurement.

EXCHANGING PISTONS IN THE DEAD-WEIGHT GAGE

When it is necessary to exchange the piston assemblies, the dead-weight gage must be partially disassembled and some of the components laid by until later. Upon removal of the internal components, a degree of hazard is involved because of the possibility of exposing the parts to harmful dirt, corrosive fingerprints, and being dropped to the table or floor. Needless to say, the small, brittle, carbide measuring piston will not survive an accidental drop. The remainder of the components, if dropped, will surely be damaged to the extent of sustaining raised burrs and will require the attention of a mechanic before reassembly.

Each manual operation that is performed on a mechanical device is accompanied by a finite degree of damage. The damage, however small it may be for the individual operations, is cumulative. It results from the imperfect execution of each manual operation. After a given length of time, the device may be expected to fail because of performance deterioration beyond the level of tolerance. It is important, therefore, to perform the manual operations with the greatest possible skill in order to keep the harmful side effects at a minimum.

There are two types of contamination that affect not only the performance of a piston pressure gage but also the mechanical state of the critical components. One contaminant is the ordinary hard partical of matter that scratches and abrades the finely-finished surfaces as it becomes entrapped between the closely-fitting members. The scratches invariably result in raised edges from the displacement of the metal and spoil the original relationship of the members. The second type of contaminant is of a chemical nature and produces harmful effects by attacking the finished metallic surfaces in a corrosive manner. Ordinary fingerprints contain water-soluble, acidic salts, having extremely high corrosive activity with the metals of the critical instrument parts. Since these parts must necessarily be handled in making a piston exchange, they may be protected from exposure to both types of contaminants by the use of clean paper wipers. Even though the parts may be completely covered with oil, salts will be deposited on the metal surfaces if they are handled with bare fingers.

There are a number of industrial paper wipers available that are relatively free of lint. After a little practice, the corrosion-sensitive parts may be safely handled with these wipers instead of with the bare fingers. Even when using the wipers as insulators, the hands should first be washed and thoroughly dried before commencing the disassembly.

The space allotted to the discussion of cleanliness is not intended to imply to the technician the impossibility of performing the job correctly, but rather to give him reassurance that the results will be quite satisfactory if he follows commmon-sense procedure of eliminating contaminations by technique alone.

Being forewarned of the hazards, the technician should wipe the bench and all instrument surfaces in the vicinity of the dead-weight gage before starting disassembly operations. A wad of wipers slightly wetted with a mild, non-toxic solvent will help to pick up the heavy oil film that invariably accumulates near the gage. Because of its tackiness, a wad so treated gathers and retains most of the accumulated dust and lint that has settled in the area.

CALIBRATION OF AN ELASTIC PRESSURE SENSOR WITH REGARD TO THE FLUID PRESSURE GRADIENT WITHIN THE SYSTEM

Modern elastic pressure sensing devices have been developed into a class of highly sensitive mechanisms having remarkable performance. The accuracy with which they are capable of measuring a given pressure is, among other things, affected by their position with respect to other members of the system.

Liquid and gaseous pressure media have mass and are subject to pressure gradients within a pressurized system. The gradients arise from the influence of gravity on the mass. For convenience, they are sometimes referred to as heads. Although the head within a particular system may have a relatively large numerical value, the net effect is often small because of a condition in which the transducer is manually adjusted to zero output at a pressure level that is not really zero. The calibration is then conducted at a level having a constant value of pressure biasing all the transducer outputs, including its zero. A question arises as to how much bias may be tolerated before the process is affected significantly.

Since it is difficult to estimate the magnitude of a pressure bias that will affect the performance of a transducer, the process may be adjusted to remove the bias. The procedure to be described may be conducted with different degrees of care depending on the range, type, and accuracy of the transducer; the magnitude of the biasing head; and perhaps, other factors.

In general, the pressure gradients become significant in the low ranges of measurement--below 1000 pounds per square inch or about 70 atmospheres.

ARRANGEMENT OF THE APPARATUS

In Figure 1, a hydraulic-type pressure transducer, having a plane, B-B, at which the sensing occurs, is shown in its relationship to the pressure standard--a piston gage. The pressure reference plane of the standard is reported by the manufacturer as occupying the position A-A. The difference in height of the two planes is determined by measurement to be h. It is apparent that the internal pressure is less at B-B than at A-A -- the difference being designated at P and expressed as

$$\Delta P = hd$$ where

d is the density of the fluid.

Integral values of pressure may be, or may have been, calculated for the piston gage pressure reference plane at A-A. Corrections for the unpredictable variations in the piston temperature are applied in the form of small metric weights having the appropriate accuracy. In a similar manner, the pressure at the reference plane at A-A may be shifted to B-B by the addition of more of the same type weights. The pressure at A-A must be increased by the amount P for the conditions shown in the figure. The quantity of mass is determined by multiplying the value P by the piston area and converting the product to convenient units of force. The value of mass thus obtained must then be placed on the piston for each pressure to be produced in the calibration of the instrument.

On most occasions, complete compensation for the existing head is not required because only a substantial reduction is necessary to satisfy the problem. Measurements in the elevation of the plane B-B over, or beneath, A-A are not critical. Furthermore, when calculating the mass required for compensation of the existing head, it is usually unnecessary to consider the change in piston area as a function of pressure. Once a figure for the position of B-B with respect to A-A has been established, the usual care in operation of the equipment is necessary.

Pressure transducers are usually small in size and a plane of reference can be estimated with a fair degree of accuracy. Some bourdon tube pressure gages of the dial indicating type, however, are quite large and have no accepted or well-defined plane to which their indicated pressures refer. The bourdon tube may be coiled into a loop of 6 to 8 inches in diameter and will have an internal pressure difference from top to bottom of up to 0.15 psi (1700 Pa). Some manufacturers choose the end of the tube socket as the reference point. There appears to be no common plane from which fluids of all the densities normally encountered will produce the same indication on a bourdon-tube gage. The selection of a reference would, therefore, be a matter of choice. There is some merit in the selection of a position whose identifying features would be visible from the back as well as from the front.

In Figure 2, the reference plane position has been chosen to pass through the pinion carrying the pointer. The pivots are easily accessible for measurements of the vertical distance to other planes of interest within the system.

Establishing integral values of pressure at the plane B-B with the standard solves only a part of the problem. If this plane is chosen as that to which all pressures are referenced, the zero indication of the transducer must also be adjusted for the same plane. Regardless of whether the transducer must be calibrated to indicate a pressure with respect to absoltue zero or with respect to the atmosphere, the procedure is the same.

A convenient way to make the adjustment is by the installation of an open-tube manometer having sufficient tube length to extend above the plane B-B. If the manometer valve is opened, the oil of the system may be forced by the pump to rise to the level B-B. With the oil standing at this level, the sensor may be adjusted to zero output. The measurement process will then refer all values of transducer output to the common datum, B-B. Transducers calibrated in absolute pressure values will have the atmospheric pressure at B-B subtracted from their stipulated calibration points for the pressures to be established by the piston gage.

The effects of liquid and gaseous head pressures are present in the equipment with which a transducer is intended to be used, as well as in the calibrating apparatus. It is just as important to pay attention to these effects in the field as it is in the laboratory. There is a need for uniform procedures in the calibration, installation and use of such devices or, in the absence of such procedures, for adequate communications between the calibrator and the user. At the least, the engineer performing the calibration should state on his calibration report the assumptions that were made during the test, the reference plane that was chosen, and the conditions under which the zero was adjusted. The user would then be able to establish the same conditions for operation of the instrument.

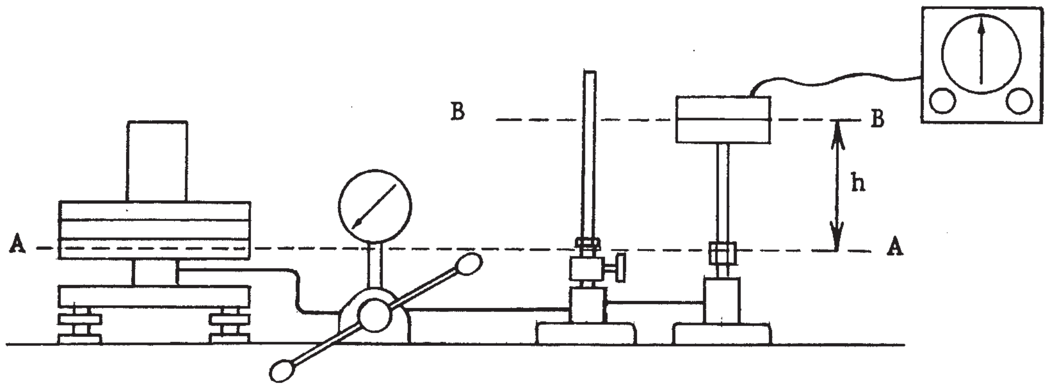


FIG. 1

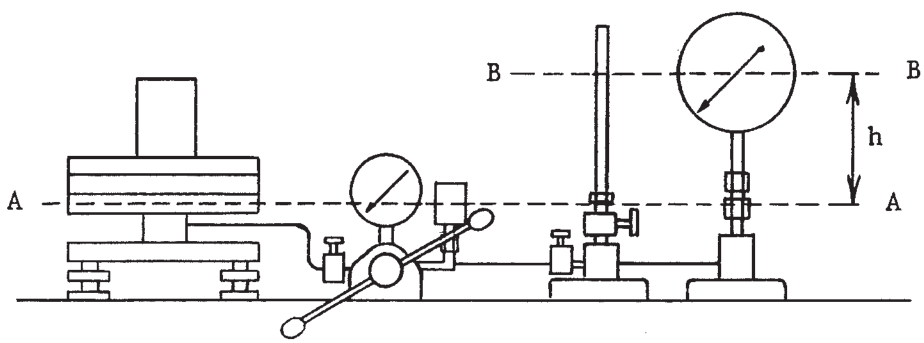


FIG. 2

STANDARD PRESSURE FOR PISTON GAGE NO.________________

OPERATING AT g_ℓ = ________________ DATE:______________

Piston No. ______________ Gravity and Buoyancy K = ________________

o(23°C) ______________ in^2 Expected Temp. (t) _____ °C Weight Set _______________

b ______________ /psi Δt _______ 1 + CΔt ___________

C ______________ /°C Therm. No. ____________

$A_{o(t)}$ ______________ in^2 Piston Tare __________ Pounds

1	2	3	4	5	6	7	8
Pressure*	1 + bp	A_e	$W=pA_e$	M = WK	Masses Used	Rem.lbs.	Gms

Expiration Date:______________

* At the reference plane of the piston.

EXPLANATION OF TABLE OF GAGE PRESSURES (FORM Q-864-1 REV. A) FOR LIQUID PISTON GAGES REFERENCED TO ATMOSPHERE

A. A minimum of six significant figures must be used in all calculations involving reported constants, weights, etc. The manufacturer's claims for accuracy assume the local gravity to be known to at least size significant figures. It is the user's responsibility to have his workbench adequately surveyed for the force of the earth's gravity.

B. Claims for accuracy allow an uncertainty of one-quarter degree Centigrade (Celsius) for the assumed temperature of the piston. If the piston temperature cannot be predicted to within these limits on the basis of history, a correction table must be computed for the remainder of Column 7. The correction may also be prepared in the form of a family of curves representing the number of grams to be added to the stack of weights for a difference in temperature from the assumed value.

C. The Symbol A_o (t) represents the effective area of the piston and its cylinder when operating at temperature t; it is obtained from the relation

$$A_{o(t)} = A_{o(t = 23)} (1 + C\,\Delta t)$$ where

$A_{o(t = 23)}$ = reported area of the piston at 23^{o}C

C = thermal coefficient of superficial expansion

$\Delta t = t - 23$

D. Gravity and Buoyancy Correction: Since the weights 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) is applied as a multiplier with the corrected value indicating the quantity of apparent mass versus brass standards required to produce the desired weights or force upon the piston.

$$K = \left[\frac{g_s}{g_\ell}\right] \left[\frac{\text{density of brass}}{\text{density of brass minus density of air}}\right]$$

$$= \left[\frac{980.665}{g_\ell}\right] \left[\frac{8.4}{8.4 - .00117}\right] \qquad \text{Where}$$

K = ratio of standard gravity to local gravity multiplied by the ratio of 1 cubic centimeter of brass weighed in a vacuum and in normal air.

g_ℓ = measured value of local gravity.

Where the mass is obtained from

$$M_A = Fk$$

If the pressure is given in the SI units of Newtons per square meter, there is no ambiguity in the force designation. When the pressure is multiplied by the area of the piston as a fraction of a square meter, the product is the required force in Newtons and is related to the masses as follows:

$$F = M g_\ell$$ Where

F = force in Newtons

M = mass in kilograms

g_ℓ = local value of earth's accelleration due to gravity in meter/sec^2.

The operator is interested in the quantity of mass to be placed on the piston, since his weights are reported in units of mass. He must therefore, divide the required force by the value of local gravity to obtain the mass. The presence of the atmosphere diminishes the force of the mass on the piston because of the buoyant effect. The magnitude of the buoyancy is determined from the volume and density of the air that is displaced by the mass. In order to simplify the calculations, the masses are reported in units of apparent mass versus brass standards so that the net force on the psiton is obtained from

$$F = M_A \, g_\ell \left[1 - \frac{\rho a}{\rho b}\right]$$ Where

ρa = density of air

ρb = density of brass

The mass is obtained from

$$M_A = Fk \quad \text{where} \quad k = \frac{1}{g_\ell \left[1 - \frac{\rho a}{\rho b}\right]}$$

E. The expiration date of the calculations will be simultaneous with that of the calibration for the piston area and of the weights.

F. Column 1, the desired pressure to be produced by the gage: The limitations of producing a given pressure are described later.

G. Column 2, the piston area must be determined for the pressure of Column 1. From the relation $A_e \equiv A_o (1 + bp)$, it is convenient to record the value of $(1 + bp)$ for possible use in the future.

H. Column 3, A_e is entered as the product of $A_{o(t)}$ and the quantity $(1 + bp)$ as entered in Column 2. A_e is the area of the piston at pressure p and at the expected temperature t.

I. Column 4, the weight load is the force required on a piston of given area to produce a given pressure

$$W = P A_{e(t)}$$ Where

W = the weight load or force on the piston

P = Pressure as indicatd in Column 1

$A_{e(t)}$ = Effective piston area at temperature t.

J. Column 5, Apparent Mass: the weights are reported in units of apparent mass versus brass standards. The required mass is obtained by multiplying the values of weight load (Column 4) by the gravity and buoyancy correction (K).

K. Column 6, Masses Used: The plates, slugs, and leaves, which constitute the total load on the piston and which correspond to the pressure we are seeking, also includes the tare components. The tare components are those that must necessarily be used for all pressure measurements. In order to determine the identity of the weights (masses) to be applied to the piston when producing a given pressure, the tare mass must first be substracted from the total mass required (the mass of Column 5).

After subtracting the mass of the tare components from the value shown in Column 5, the largest possible value of apparent mass shown on the table of weights is subtracted from the remainder. The process is continued, each time subtracting the largest possible value on the table from the remainder until all possible weights have been used. If the subtraction has been made correctly, there will be a remainder that is smaller than the smallest weight of the set. The manufacturers claims for accuracy of the instrument do not consider discrete increments of pressure as a source of error in the measurement. The remainder (Column 7) may be regarded in one of the following ways:

1. If it is imperative to establish an integral pressure as nearly as possible, the weight set may be supplemented with additional fractions calibrated either in pounds mass or grams mass. The quality of the weights

should be similar to that of the weight set of the dead weight gage.

2. The observed reading or indication of the device being calibrated may be corrected for the error in the pressure. The remainder, which appears in Column 7 as pounds, must, of course, be expressed in units of pressure.

L. Columns 7 and 8, Remainder: The reaminder is tabulated in both pounds mass and grams (mass) to be used in whatever manner is most convenient for correction of the nominal pressure of Column 1.

The suggestion of using grams as small fractions rather than pounds is for economical reasons. Most laboratories have, or can obtain, a set of calibrated metric weights.

There are other reasons for adding mass to the load on the piston at the time of the measurement. If the temperature of the gage is higher than the predicted one, the piston area is larger and requires more load upon it than was calculated. The additional load is obtained from tables or curves which have been prepared for the gage being used.

Finally, it is sometimes convenient to add load on the piston to compensate for the effects of liquid heads that may be present in a particular arrangement of the apparatus.

USING THE TEMPERATURE CORRECTION CURVES FOR RUSKA DEAD WEIGHT GAGE

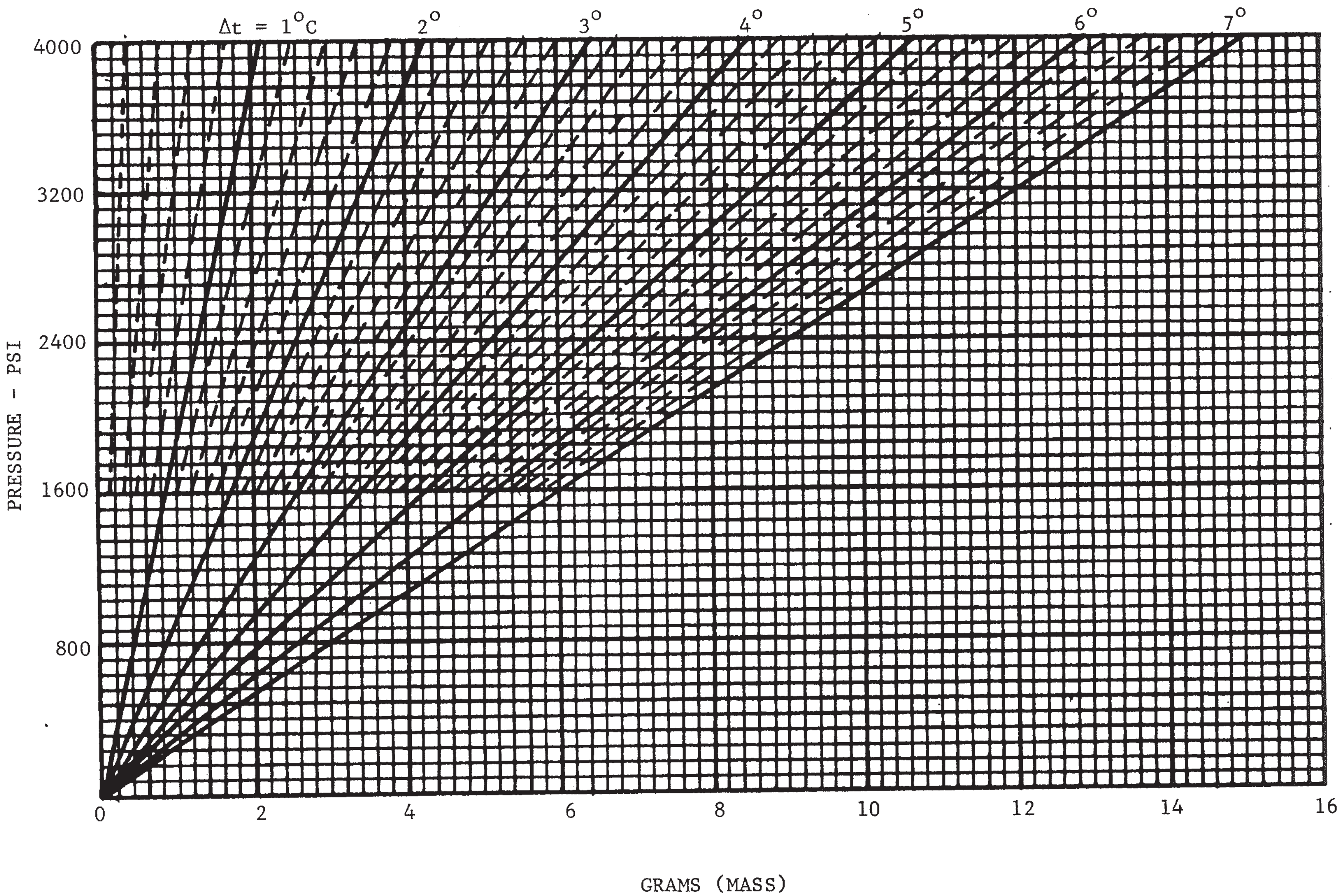
When the dead weight gage is used as a standard of pressure in the calibration of elastic pressure sensors, it is economical to make corrections for the variables in advance. Usually, the corrections are applied for the fundamental values of pressure that occur repeatedly. A confusing point in the procedure is the necessity for the operating temperature of the gage to be predicted. The gage temperature, of course, fluctuates between certain limits, depending on the environment and the nature of the calibration so that an accurate prediction is not always possible.

If the advance calculations for pressure correction are made for a temperature that is lower than the expected operating temperature, the weight load on the piston would then be too small. During operation, the piston area would be larger than that used in the calculations. It would then be possible to add weight in some convenient form that would compensate for the deficit. Standard Class S laboratory metric weights are entirely suitable for this purpose. The accompanying chart indicates the quantity of weight to be added to the piston for several values of t--the difference between the observed temperature and the computed temperatures--and for the working pressure.

TEMPERATURE CORRECTION CURVES FOR RUSKA MODEL 2480/2481 FOR PISTON AREA 0.130 IN^2

WORKING PRESSURE VERSUS CORRECTION IN GRAMS (MASS) TO BE ADDED TO WEIGHTS ON THE GAGE

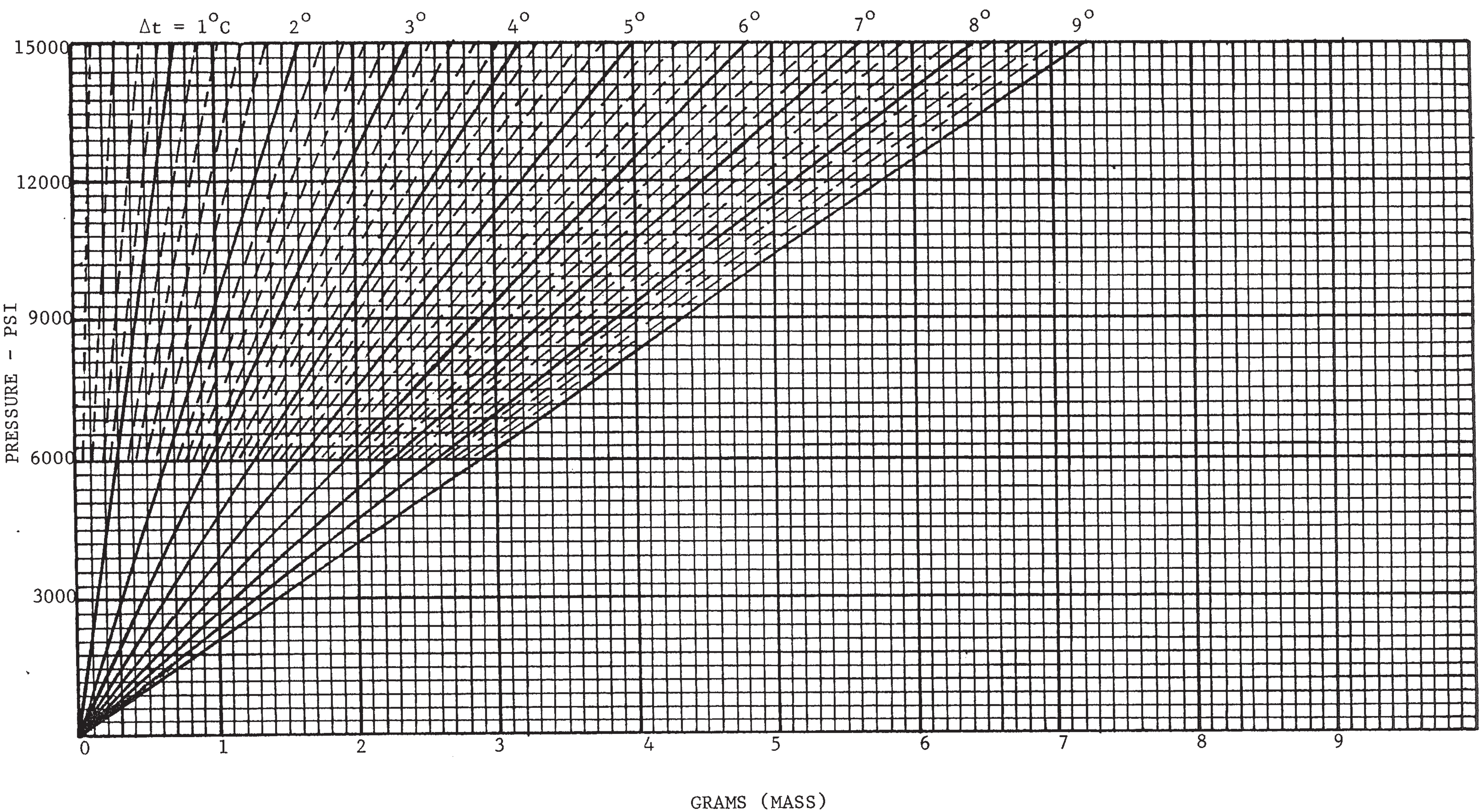
FOR TUNGSTEN CARBIDE PISTON AND CARBIDE CYLINDER WITH COMBINED COEFFICIENT, $C = 9.1 \times 10^{-6}$ $IN^2/IN^2/^{\circ}C$



TEMPERATURE CORRECTION CURVES FOR RUSKA MODEL 2480/2481 FOR PISTON AREA 0.013 IN

WORKING PRESSURE VERSUS CORRECTION IN GRAMS (MASS) TO BE ADDED TO WEIGHTS ON THE GAGE

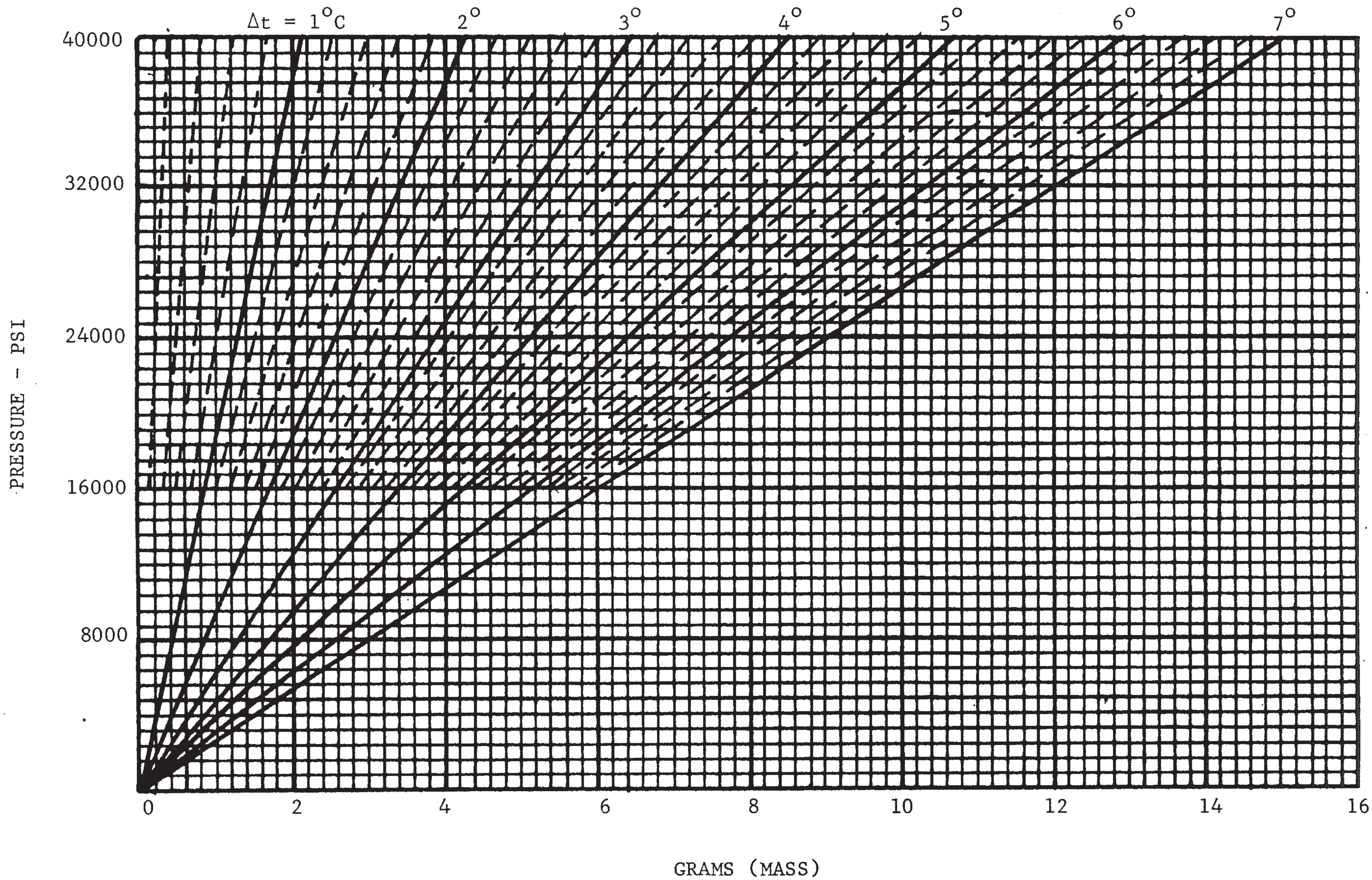
FOR TUNGSTEN CARBIDE PISTON AND CARBIDE CYLINDER WITH COMBINED COEFFICIENT, $C = 9.1 \times 10^{-6}\ IN^2/IN^2/^{\circ}C$



TEMPERATURE CORRECTION CURVES FOR RUSKA MODEL 2480/2481 FOR PISTON AREA 0.013 IN^2

WORKING PRESSURE VERSUS CORRECTION IN GRAMS (MASS) TO BE ADDED TO WEIGHTS ON THE GAGE

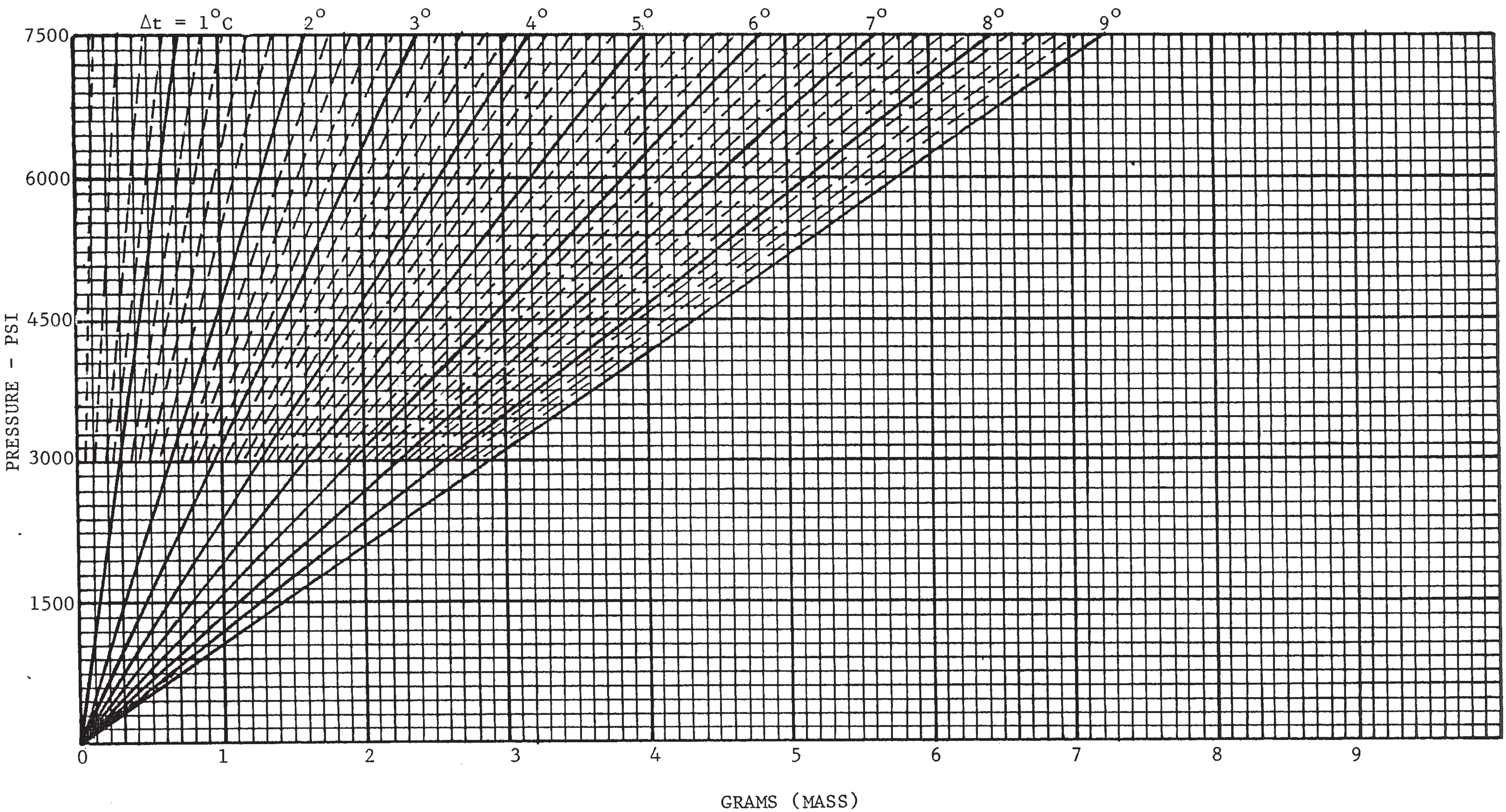
FOR TUNGSTEN CARBIDE PISTON AND CARBIDE CYLINDER WITH COMBINED COEFFICIENT, $C = 9.1 \times 10^{-6}\ IN^2/IN^2/^{\circ}C$



TEMPERATURE CORRECTION CURVES FOR RUSKA MODEL 2480/2481 FOR PISTON AREA 0.026 IN^2

WORKING PRESSURE VERSUS CORRECTION IN GRAMS (MASS) TO BE ADDED TO WEIGHTS ON THE GAGE

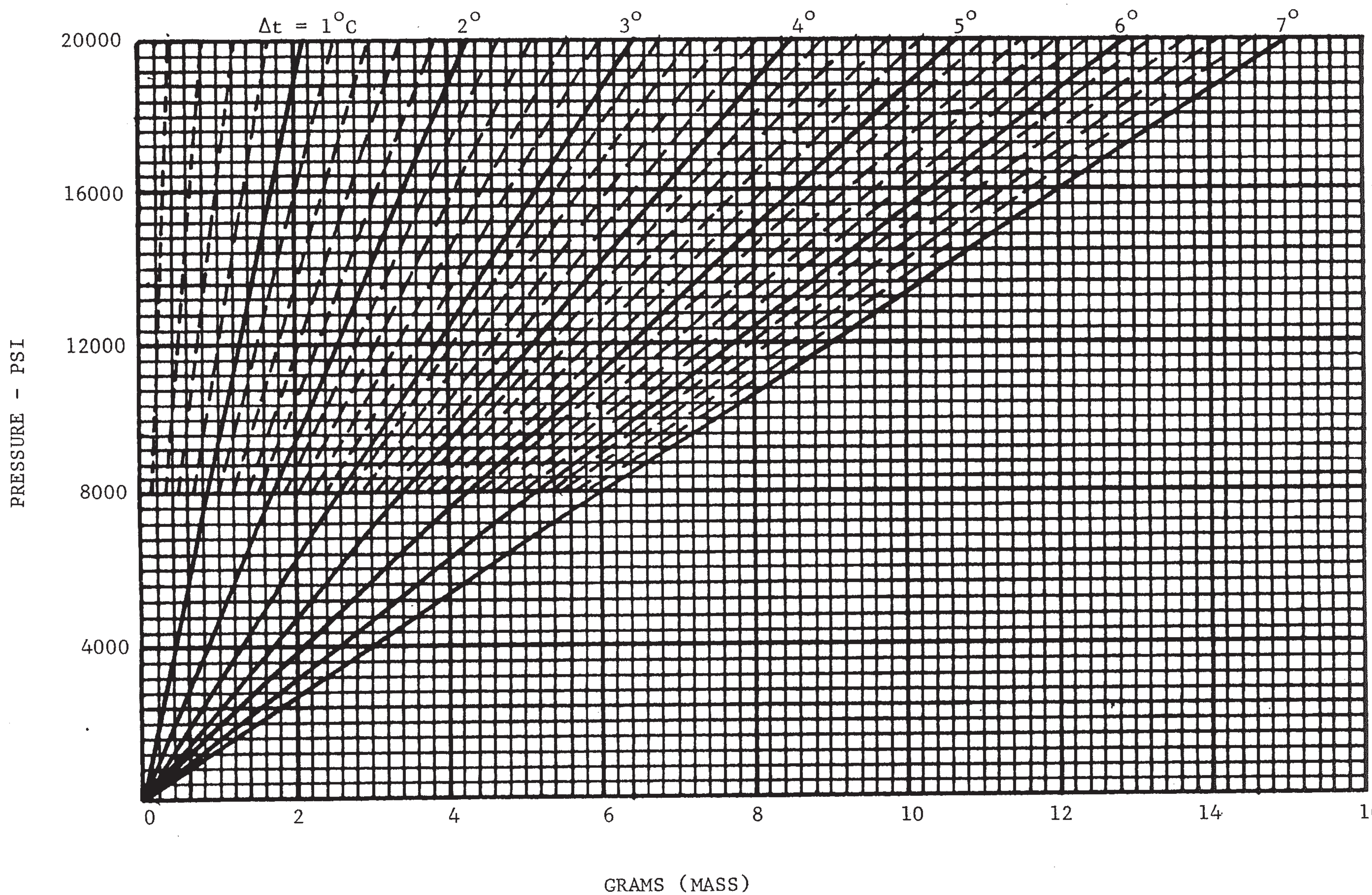
FOR TUNGSTEN CARBIDE PISTON AND CARBIDE CYLINDER WITH COMBINED COEFFICIENT, $C = 9.1 \times 10^{-6}\ IN^2/IN^2/^{\circ}C$



TEMPERATURE CORRECTION CURVES FOR RUSKA MODEL 2480/2481 FOR PISTON AREA 0.026 IN^2

WORKING PRESSURE VERSUS CORRECTION IN GRAMS (MASS) TO BE ADDED TO WEIGHTS ON THE GAGE

FOR TUNGSTEN CARBIDE PISTON AND CARBIDE CYLINDER WITH COMBINED COEFFICIENT, $C = 9.1 \times 10^{-6}$ $IN^2/IN^2/^{\circ}C$



SECTION V

MAINTENANCE AND CALIBRATION

RECALIBRATION INTERVAL FOR HYDRAULIC DEAD WEIGHT GAGES

On a number of occasions, Ruska has been asked the question, "For what period of time is the calibration of a dead weight gage reliable?" Considerable expense could be avoided if a dependable figure were known in answer to this question.

The period of time for which the calibrated values of a dead weight gage are valid depends upon two factors--the rate of decay or deterioration of the original accuracy and the total deterioration that may be tolerated. Deterioration of the accuracy results from unpredictable changes in the piston area and in the mass of the weights. These changes occur as a result of normal and abnormal wear of the critical parts and, to some extent, from dimensional aging effects of the construction materials. The changes begin immediately after calibration. Estimates of the magnitude of the changes are obtained from the results of recalibrations of number of gages having been in service for a period of time.

The recalibrated values for a group of 15 pistons were found to indicate an average annual change in area of less than 3.5 parts per million. A similar study of a group of 90 weights indicated that the average annual change in mass would not be expected to exceed 1.3 PPM. These figures were not obtained from a statistical treatment of the date. They represent the numerical average of changes in the nominal values reported to the customer. No allowance was made for the care with which the gages had been operated during the period in question. Some gages were in very good condition when received for recalibration; others were in very poor condition. All gages were cleaned and tested for resolution before recalibration. Some gages had minor repairs before recalibration, but the labor was considered to have increased the changes from what they would normally been. Minor repairs were, therefore, not regarded as a reason for rejecting any of the pistons studied. None of the weights had repair labor; they were only cleaned before recalibration.

The figures for the average annual change were obtained from samples manufactured sometime in the past. They are not truly representative of what would be expected from samples of current production. Improvements in the art and in materials naturally result in improvements in performance and longevity. Present models would, therefore, be expected to change less than the numbers shown above.

Assuming a change in overall accuracy of 0.0025% (25PPM) could be tolerated, the expected life of a calibration would be approximately four to five years. Some allowance must be made for the fact that the figures quoted are average ones and would be greater in some instruments. Also, the figures would be valid only in instances where the instrument was operated properly and was not subject to abnormal wear.

DISASSEMBLY

The drive belt is removed from the motor pulley and is pulled toward the forward part of the gage. To insure that the belt has not been left off after the gage has been loaded with weights, it is advisable to leave the drive belt encircling the pressure housing assembly, Part 2480-100/2481-100.

With the belt forward and out of the way, the area between the housing and motor drive serves as a space to lay the parts as they are removed from the housing. A new, clean piece of paper is placed on the base surface to keep the parts clean. The heavier type industrial wipers serve for this purpose.

After preparing the gage and bench for removal of the piston assembly, the operator should wash and thoroughly dry his hands.

Referring to Figure 1.1, the WEIGHT TABLE, is constructed to Type 303 stainless steel and may be safely handled with the bare fingers. The TABLE SUPPORT, to which the table is securely attached, is made of heat-treated alloy steel and should not be touched with the fingers.

It may be seen from Figure 1 that the WEIGHT TABLE rests on the THRUST BEARING when in the down position. The bearing is designed to accommodate the load of all the weights smaller than the sleeve weight when there is no pressure in the gage. Since the TABLE SUPPORT does not rest on the MEASUREING PISTON THRUST PLATE when in this position, the piston is protected from damage by an impact upon the weight-loading table. The THRUST BEARING is protected from overload by the stack of large weights by the drive-sleeve thrust bearing (5-129). With no pressure in the housing, the sleeve weight rests on a shoulder of the driving sleeve and stands clear of the WEIGHT TABLE. The accidental loss of pressure will not result in an impact on the MEASURING PISTON THRUST PLATE but on the Drive Sleeve Thrust Bearing.

In changing piston assemblies, it is necessary only to remove the TABLE SUPPORT BUSHING from the pressure housing and force the installed cylinder out with the oil pump. Pin Wrench #99199-008, contained in spare parts kit 2480-102, is used to unlock the bushing from the housing, after which the entire TABLE SUPPORT BUSHING and WEIGHT TABLE ASSEMBLY may be unscrewed with the fingers. The knurl on the RETAINING NUT is provided for this purpose. It is advisable to avoid touching the TABLE SUPPORT BUSHING more than necessary with the bare fingers because of the possibility of transferring corrosive fingerprints to the alloy steel. When withdrawing the assembly, it should first be lifted carefully above the housing to expose the lower end of the bushing. Occassionally, the cylinder will cling to the lower surface of the bushing as the assembly is being removed. On such occasions, the free hand should be held under the assembly to catch the cylinder in the event it should fall during transfer to the table top. In the event it does not cling to the bushing, the cylinder may be forced out of the housing by pumping in a quantity of oil with the hand pump.

As the pumping is started, and, before the cylinder begins to move, the piston will rise to its upper limit. The small MEASURING PISTON THRUST PLATE may be grasped with the fingers, which are insulated with a wiper. The pumping must be continued until the cylinder is free of the housing bore, at which time the assembly may be lifted out and immediately wrapped with a wiper.

REASSEMBLY OF THE GAGE

Assuming that a different piston assembly is to be placed in the gage, the second piston is removed from its container, in much the same way that the first one was removed from the housing. Since the second piston is covered with oil, the assembly will be a little more difficult to remove from the container. The assembly must be moved from side-to-side in the container while gently lifting by the MEASURING PISTON THRUST PLATE in order that the air may enter beneath the cylinder.

Before installing the replacement piston-cylinder assembly, the top mating faces of the cylinder and piston should be wiped free of lint. Lint which clings to the outside diameter of the cylinder is not objectionable, since it will be pushed aside during assembly. The replacement assembly is inserted into the housing while being suspended by the MEASUREING PISTON THRUST PLATE. These assemblies are always handled with paper wipers as insulators against contamination by fingerprints. With the valve to the reservoir open, the assembly may be pushed into the housing by pressing on the MEASURING PISTON THRUST PLATE. After a final wipe across the THRUST PLATE with a wiper, the WEIGHT TABLE and TABLE SUPPORT BUSHING ASSEMBLY is replaced.

Upon completion of the assembly, the drive sleeve is rotated so as to expose the bleed screw (2450-100-3). The screw is removed with a 3/32 hex key and the drive sleeve rotated until the port is covered but is still visible. Oil is pumped into the housing until bubbles cease to appear in the vent port, after which the screw is replaced.

RUSKA MODEL 2480/2481 PISTON GAGE

PREPARATION AND SHIPMENT FOR RECALIBRATION

When submitting a Ruska Model 2480 or 2481 Piston Gage for recalibration or repair, the components and parts listed should be shipped.

Return the following to Ruska:

1. Complete weight set
2. Extra piston assemblies
3. Everything shown in Figure 1.1

a. When shipping the gaging elements without the pressure housing assembly, place all piston assemblies in the container provided. Place the WEIGHT TABLE assembly and TABLE SUPPORT BUSHING in a strong plastic bag as one assembly. Secure the bag with tape, wrap with shipping foam or other suitable material, bind the foam in place with tape.

b. When shipping the extra piston assembly in the container, make certain the aluminum spacer ring is in place above the cylinder before the cover is screwed down. This ring will limit the freedom of the cylinder within the container.

c. When shipping the instrument base prepare a shipping box as shown in Drawing 2480-101-10. Check that the 8-32 x 1" hollow head cap screw (2452-4-10) is securely in place in the lower section of the rotating drive sleeve. Invert a small but strong plastic bag over the weight-loading table and wrap it tightly around the drive sleeve. Secure the bag with several turns of masking tape or reinforced binding tape. Insulate the top portion of the housing and weight-loading table with 1/2-inch or more of foam or other suitable material. Bind the foam in place.

   Use cushioning material around the edges of the triangular base when anchoring the instrument in the box. The extra parts may be taped to the housing or packed in a separate package and secured inside the box.

d. The weights should not be permitted to chafe against the slots in the shipping box. Insulate the weights with a strong plastic bag folded so as to take up the clearance. Bind the boxes with steel banding ribbon for additional strength.

Shipment by motor freight is entirely satisfactory.

MODELS 2480 AND 2481 DEAD WEIGHT GAGE

WEIGHT-LOADING TABLE SUBASSEMBLY

Instructions for Disassembly/Reassembly

In the Models 2480 and 2481, the stops that limit the axial movement of the piston are located in the WEIGHT TABLE ASSEMBLY. In this position, the stops may be made stronger than those which are usually attached to the MEASURING PISTON. The piston is afforded virtually complete protection from THRUST PLATE shock through the WEIGHT TABLE assembly.

The main elements that make up the WEIGHT TABLE assembly are assembled are designed so that the TABLE SUPPORT can be removed for periodic redetermination of the mass without disturbing the very precise alignment set by the Ruska calibration department.

Disassembly Procedure

1. Invert the WEIGHT TABLE on a clean piece of paper.
2. Remove the RETAINING RING.
3. Remove the RETAINING NUT.

Reassembly Procedure

Assuming the parts have been thoroughly cleaned with a volatile degreasing solvent and that the mass has been determined, proceed as indicated while referring to the Figure 1.1 nomenclature. The parts should be handled by whatever means is convenient that will avoid transferring fingerprints to the surfaces. Industrial paper wipers are satisfactory.

1. Invert the WEIGHT TABLE on a clean piece of paper.
2. Carefully replace the RETAINING NUT.
3. Replace the RETAINING RING makeing sure it is fully seated.

SECTION VI

ILLUSTRATIONS AND PARTS LIST

2480-102 SPARE PARTS AND ACCESSORIES

RIC NO.	DESCRIPTION	QUANTITY
2400-1-82	COVER,DUST - DEAD WEIGHT GAGE	1
2400-1-83	COVER,SLEEVE-DEAD WEIGHT GAGE	1
2450-1-8	RING,BACKUP -40KPSI DEAD WT GAGE	2
2480-101-6	FOOT PLATE	3
26-206	MINIATURE FUSE LITTLE 1/2A 250V	2
54-700-212	O-RING BUNA N 1/8 X 7/8	6
54-700-451	O-RING BUNA N	1
54-900-18	O-RING 3/4 X 7/8 BUNA N, 90 DURO	3
55-500	OIL GAL DWG ASSEMBLY	1
86-802	TBG TYGON 3/8OD X 1/16W	6 FT
94-608	WR 3/32 ALLEN WRENCH CAD PLT	1
94-618	WR SPANNER 2-1/4"	1
94-646	WR SPANNER 1-1/4"	1
99199-008	WRENCH,PIN	1

RUSKA MODEL 2400 PISTON GAGE

PREPARATION AND SHIPMENT FOR RECALIBRATION

When submitting a Ruska Model 2400 Piston Gage for recalibration or repair, the components and parts listed below should be shipped.

1. Items to be submitted--Refer to Drawing No. 2400.

   a. Instrument Base, P/N 1, with complete pressure housing assembly, P/N 2400-006-0.

   b. Piston assembly, 901, and weight-loading table, 903, assembled to pressure housing as in normal use.

   c. Extra piston assembly, 902, in container, 907, and weight-loading table, 904.

   d. Complete weight set, 2401 (Metric) or 2402 (English).

2. Preparation for shipment.

   a. Check that the round-head #10 x 1/4"-long retaining screw is securely in place in the lower section of the rotating drive sleeve, P/N 8. With a piston assembly and weight-loading table in place within the pressure housing, invert a small but strong plastic bag over the weight-loading table and wrap it tightly around the drive sleeve. Secure the bag with several turns of masking tape or reinforced binding tape. Insulate the top portion of the housing and weight-loading table with 1/2-inch or more of foam or other suitable material. Bind the insulation in place.

   b. When shipping the extra piston assembly in the 907 container, make certain the aluminum ring is in place above the cylinder before the cover is screwed down. This ring will limit the freedom of the cylinder within the container.

c. Wrap the extra weight-loading table in clean, heavy plastic film. Do not touch the spindle with bare fingers or scratch it during handling, as it is a highly functional part and is subject to severe corrosion. Insulate the entire assembly against impact damage and secure the insulation with additional wrappings of plastic and tape.

d. Prepare a shipping box as shown on the Drawing 2400-205. Use cushioning material around the edges of the triangular base when anchoring the instrument in the box. The extra parts may be taped to the housing or packed in a separate package and secured inside the box.

e. The weights should not be permitted to chafe against the slots in the shipping box. Insulate the weights with strips of corrugated paper folded so as to take up the clearance. Bind the boxes with steel banding ribbon for additional strength.

Shipment by motor freight is entirely satisfactory.