TELEDYNE HASTINGS INSTRUMENTS

INSTRUCTION MANUAL

MODEL NALL
MASS FLOWMETERS

PRELIMINARY

TELEDYNE INSTRUMENTS
Hastings Instruments
A Teledyne Technologies Company

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KEMA CERT 10192.01
Accredited by the Dutch Council for Accreditation (RvA)
Accredited by the Registrar Accreditation Board (RAB)

Manual Print History

The print history shown below lists the printing dates of all revisions and addenda created for this manual. The revision level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new revision is created, all addenda associated with the previous revision of the manual are incorporated into the new revision of the manual. Each new revision includes a revised copy of this print history page.

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SECTION 1

General Information

1.0 GENERAL INFORMATION

1.1 Features:

Hastings Linear Mass Flowmeters are designed to accurately measure mass flow without corrections or compensations for gas pressure and temperature. Due to a linear electrical output signal, the flowmeters are ideal for use with totalizers and recorders. Hastings Linear Mass Flowmeters do not require any periodic maintenance under normal operating conditions with clean gases. No damage will occur from the use of moderate overpressures, overflows, or liquid solvents.

The standard flowmeter calibration is for air. Special calibrations for most other gases such as oxygen, nitrogen, hydrogen, and carbon monoxide, ar eavailbale on special order, or by use of a gas multiplier. Special calibrations are noted by the following options such as OPT-G (special gas) or OPT-R (special range) and OPT-GR (special gas and range).

Standard HS-Series transducer and L-Series laminar flow elements are available with 300 Series stainless steel or monel construction. U-Series low pressure drop transducers are constructed of monel.

The basic flowmeter is available in either a cabinet model or a NIM panel. The NIM model can be mounted side by side in groups of three, in an optional NIM frame. Chassis models are available on special order.

PRELIMINARY

2.0 OPERATING PRINCIPLE

Hastings Linear Mass Flowmeters operate on a unique electrical principle whereby a capillary tube is heated uniformly by a transformer. The temperature distribution is symmetrical about the midpoint at zero flow (see Figure 2.1) and external thermocouples TC-1 and TC-2 develop equal and opposing outputs.

When flow occurs through the tubing, heat is transferred to the gas and back again creating an asymmetrical temperature distribution. For a constant power input, the differential thermocouple output is a function of the mass flow rate and heat capacity of the gas. Since the heat capacity is relatively constant over wide ranges of temperature and pressure, the flowmeter may be calibrated directly in mass units for any given gas. Changes in gas composition only require simple multiplier applied to the air calibration (see table, page 19) to account for the difference in heat capacity, thus the flowmeter is capable of measuring a wide variety of gases.

High ranges of flow are achieved by dividing the flow with a fixed ratio shunting arrangement, as is illustrated in Figure 2.2. By placing the measuring tube in parallel with one or more dimensionally similar channels (laminar flow elements), viscous restrictions are created. Therefore, the sensor need heat only a small portion of the total gas which results in low power requirements while retaining mass measuring characteristics.

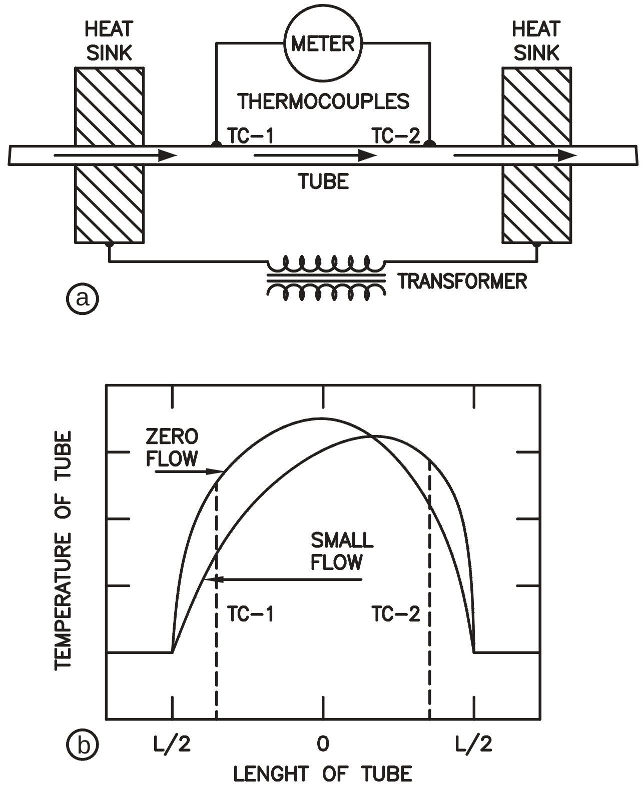
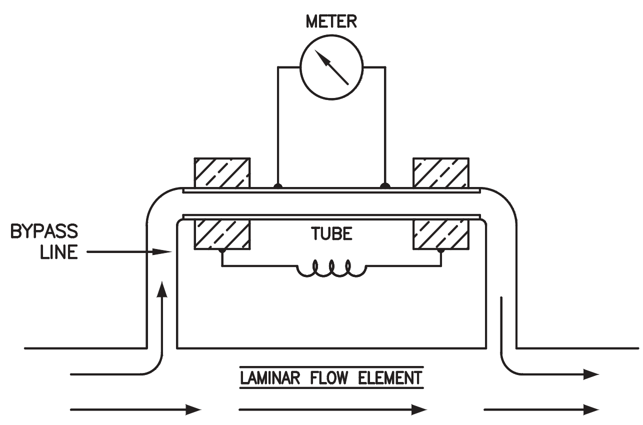


fig 2.1

Heated tube thermal flowmeter (a) schematic, (b) temperature distribution under static and flowing conditions



Thermal flowmeter with laminar flow element

fig 2.2

3.0 RECEIVING AND INSPECTION

3.1 Initial Inspection:

Carefully unpack the Hastings Linear Mass Flowmeter and inspect it for any obvious signs of damage due to shipment. Immediately advise the carrier who delivered the shipment of any suspected damage.

3.2 Packing List:

The basic flowmeter consist of four separate parts:

1. The power supply (NALL, NALL-P, NALL-P/CC, DNALL-P, TNALL-P, NALL-C, etc.)
2. The transducer (examples: HS-10S, HS-50KM, etc.)
3. The connecting cable (examples: NF-8-NM, NF-25-NM, etc.)
4. The laminar flow element attached to transducer, for ranges higher than 0-100 SLPM (examples: L-5S, L-100SF, L-200MF, etc.)

Optional equipment or accessories will be listed as part of the model number or listed separately on the packing list. (See Section 11.0, OPTIONS AND ACCESSORIES.)

3.3 Decimal Point Setting:

The digital flowmeter has a 3-digit LED display. The decimal point is set as shown in the table below:

TRANSDUCER		
HS-10S/HS-10M	Ö	9.99 SCCM
HS-50S/HS-50M	Ö	50.0 SCCM
HS-100/HS-100M	Ö	99.9 SCCM
HS-500/HS-500M	Ö	500 SCCM
HS-1KS/HS-1M	Ö	999 SCCM
HS-5KS/HS-5M	Ö	5.00 SLPM
HS-10KS/HS-10M	Ö	9.99 SLPM
HS-50KS/HS-50M	Ö	50.0 SLPM
HS-100KS/HS-100M	Ö	99.9 SLPM

LFE, using HS-10S or HS-10M:		
L-5S/L-5M	………	5.00 SCFM
L-10S/L-10M	………	9.99 SCFM
L-25S/L-25M	………	25.0 SCFM
L-50SF	………	50.0 SCFM
L-100SF	………	99.9 SCFM
L-200SF	………	200 SCFM
L-500SF	………	500 SCFM

U-SERIES TRANSDUCER		
U-50M	ÖÖÖ	50.0 SCCM
U-100M	ÖÖÖ	99.9 SCCM
U-500M	ÖÖÖ	500 SCCM
U-1KM	ÖÖÖ	999 SCCM
U-5KM	ÖÖÖ	5.00 SCCM
U-10KM	ÖÖÖ	9.99 SCCM
U-3M/LU-2M	ÖÖÖ	20.0 SCCM
U-3M/LU-3M	ÖÖÖ	50.0 SCCM

fig 3.3

3.4 Power Source:

Connect the power supply to 115 volt (10%) 50-60 Hz line. (The prefix "E" indicates the power supply is to be connected to a 230 volt (10%) 50-60 Hz line.) Connect the power supply to the transducer by means of the connecting cable. When the flowmeter is first turned on, the readout may fluctuate somewhat, before settling to a steady indication.

3.5 Electrical Zero:

After allowing a warm-up time of approximately 30 minutes, close off the INLET and OUTLET connections on the transducer with the protective plastics end caps shipped on the transducer. If the meter does not indicate zero flow, adjust the "ZERO" potentiometer located on the front panel, until the meter indicates zero.

3.6 Indication of Flow:

Remove the end plug or end cap from each end of the transducer and blow air into the inlet side. (The meter readout should increase indicating the flowmeter is in good working order and ready for installation.)

Installation Instructions

4.0 INSTALLATION INSTRUCTIONS.

4.1 TRANSDUCER

4.1.1 Orientation of the Transducer

The transducer may be mounted in any position, as long as the direction of gas flow through the transducer is from “IN” to “OUT” as marked on the transducer base. (U-Series transducers should be mounted in a horizontal position only.)

4.1.2 Mounting the Transducer

There are two ¼-20 threaded holes 3/8” deep in the bottom of the transducer that can be used to secure it to a mounting bracket, if desired. When the transducer is used in combination with an L or LU Series Laminar Flow Element (LFE), the LFE should be supported instead of the transducer to prevent undue strain on the connectors between the transducer and the LFE. Standard pipe support rings or pipe hangers are usually satisfactory for supporting the LFE.

4.1.3 Inlet and Outlet Connections

The table 4.1 describes the inlet and outlet connections for all standard transducers. (If it is necessary to reduce the pipe size or install an elbow on either side of an L or LU Series Laminar Flow Element, it is recommended that a straight pipe 12” in length, and of pipe or flange size stated below, be connected directly to the LFE before connecting a smaller diameter pipe or an elbow.)

TRANSDUCER CONNECTIONS

TRANSDUCER TYPE		PIPE SIZE
HS-10S, HS-10M	......	1/8" NPT F
HS-50S, HS-50M, HS-100S, HS100M, HS-500S, HS-500M	......	1/4" NPT F
HS-1KS, HS-1KM HS-5KS, HS-5KM	......	1/2" NPT M
HS-10KS, HS-10KM HS-50KS, HS-50KM HS-100KS, HS-100KM	......	3/4" NPT M
U-50M, U-100M	......	1/4" NPT F
U-500M, U-1KM	......	3/4" NPT F
U-5KM, U-10KM	......	1-1/2" NPT M

TRANSDUCER TYPE		PIPE SIZE
L-5S, L-5M	......	1" NPT
LS-10S, L10M	......	1-1/2" NPT
L-25S, L-25M	......	2" NPT
L-50SF	......	3" ASA *
L-100SF	......	4" ASA *
L-200SF	......	6" ASA *
L-500SF	......	8" ASA *

*** 150-lb.flange**

TRANSDUCER TYPE (LFE)		PIPE SIZE
LU-2M	......	2" NPT
LU-3M	......	3" NPT

Table 4.1

4.1.4 Sealing the Threaded Connections

Many users find that Teflon tape is an excellent sealant for most applications, however, any sealant material compatible with the flow system is acceptable. Caution must be exercised during assembly and disassembly of the threaded connections to prevent shreds of the Teflon tape, or the sealant from entering the flow line, where they could block the small passages in the transducer.

The us of O-ring seal connectors on the transducers with female threads is often more convenient for many low pressure applications, such as with U-Series transducers.

4.1.5 Checking for Leaks

Check the transducer connections for leaks by pressurizing the line to the operatingpressure (not to exceed 250 psig except on high pressure models), and applying a diluted soap solution to the pipe joints. Any gas escaping from the pipe joints will cause a continuous stream of bubbles.

4.2 FILTERS:

If the flow stream carries particles large enough to block the small passages inside the transducer (approximately .02" ID) a filter should be installed in the flow line of the inlet side of the transducer.

4.3 CABLES

4.3.1 Description

A standard 5-conductor 20 gauage shielded 8-foot long cable (NF-8-NM) is normally ordered with each flowmeter and is used for connecting the power and the transducer. Longer cables are available upon special request.

4.3.2 Cable Length

The cable length can be extended to 25 feet without changing the calibration of the flowmeter by more than SP+/-1% of the rated full scale flow. Cables longer thtan 25 feet will cause the indicated flowrate to be lower than the actual flowrate and recalibration may be required. (See Section 7.0 for calibration procedures.)

4.3.3 Cable Conductor Size

In the event cable conductors larger than #20 are desired, the connecting cable can be extended to greater lengths without having to recalibrate the flowmeter. The table below shows the relationship of the conductor size to the maximum cable length that can be used without changing the calibration by more than 1% of full scale.

Maximum Cable Length Vs Wire Gauge

Cable Conductor Gauge	Maximum length Without recalibration
#20 ……………………………...	25 feet
#18 ……………………………...	40 feet
#16 ……………………………...	65 feet
#14 ……………………………...	100 feet

fig 4.3

4.4 POWER SUPPLY:

4.4.1 Mounting

One type of housing available for the power supply is a small metal cabinet, 7.75” X 5.75”X 5.75”, which can sit on a table or desk or can be mounted securely on a bracket. The “NIM” style package is 5.41” X 8.71” X 9.68”, and can be housed in an 8.75” X 19.00” relay rack-panel.

4.4.2 Electrical Connections

Connect the power supply to the transducer with the NF-8-NM connecting cable (Section 4.3) and connect the AC line cord to a suitable power source (Section 3.4).

4.4.3 Electrical Zero Check

Turn the power supply "ON" and allow the flowmeter 30 minutes to warm up. Stop all flow through the transducer and check the electrical zero.

CAUTION: DO NOT ASSUME THAT ALL METERING VALVES WILL COMPLETELY SHUT OFF FLOW. EVEN A SLIGHT LEAKAGE THROUGH A VALVE WILL CAUSE AN INDICATION ON THE METER WHICH WILL FALSELY APPEAR TO BE A ZERO SHIFT.

If necessary, adjust the "ZERO" potentiometer located on the front panel of the power supply, until the meter indicates zero.

SECTION 5

Using the Flowmeter

5.0 USING THE HASTINGS LINEAR MASS FLOWMETER

5.1 Warm-Up Time:

When the flowmeter is first turned on, the meter will fluctuate somewhat before settling to a stable indication. The flowmeter indicates the mass flow to +/- 3% of full scale in about 5 minutes, but should be allowed to warm up for 30 minutes to achieve maximum accuracy.

5.2 Response Time:

The response time to a change in flow is logarithmic and is approximately 7 secs. For a 67% change and 30 secs. for a 90% change. Pneumatic imbalance in the associated plumbing will often cause the response time to appear longer due to additional time required for flow to stabilize in the system. If a faster response time is desired, consult the factory.

5.3 Mass Flow Units:

The units of mass flow used with the Models NALL, ENALL, NALL-P, and ENALL-P mass flowmeters are the "standard cubic centimeter per minute" (SCCM) and/or the "standard litre per minute" (SLPM). An SCCM is the volume occupied by a given mass of gas at a specified temperature and pressure referred to as standard conditions (STP). These conditions are defined as 0° C (32°F) and 760 Torr (14.7 psia). A one litre volume of gas is equivalent to 1000 cm³ of the same gas. Those models incorporating a Laminar Flow Element (LFE) use "standard cubic foot per minute" (SCFM) units, which are equivalent to a flow of 28,300 SCCM or 28.3 SLPM. To convert to other units of mass flow, multiply the mass flow rate of the gas by the density of the gas at standard conditions.

Example: What is the equivalent mass flow in grams per minute of 100 SCCM of air?

Solution: The density of air at 0° C and 760mm of Hg is .00129 gm/cm³.

Mass Flow = 100 SCCM X .00129 gm/cm³.

= .129 gm/min.

5.4 Special Factory Calibrations:

All Hastings Mass Flometers are calibrated for air unless otherwise specified. Calibrations for a special range or for a gas other than air are clearly indicated on the front panel readout of standard models, or by special comments or curves in the manual. Calibrations traceable to the National Institute of Standards & Technology (NIST), can also be made for an extra charge.

5.5 Gas Conversion Factors:

The Hastings Linear Mass Flowmeter can be used for many different gases as long as the gas is compatible with materials of construction. No electrical adjustments are necessary when using the gas conversion factors so the original calibration is undistrubed.

5.5.1 Flowmeters Factory Calibration for Air

A flowmeter originally calibrated for air can measure other gases by using the Hastings Gas Conversion Factors on Page 35 of this manual. Simply multiply the meter indication by the appropriate gas conversion factor (K).

Example: What is the actual flow rate of Helium through a flowmeter calibrated for Air if the meter reading is 50 SCCM?

Solution: From the table on page 35, the gas conversion factor for Helium is 1.382.

Actual flow = meter reading X (K_{He})

= 50 SCCM X 1.382

= 69.1 SCCM of Helium

5.5.2 Flowmeter Factory Calibrated for a Special Gas

If the Hastings Linear Mass Flowmeter is calibrated for a gas other than air, it may also be used to measure the flow rate of many other gases. The flow rate will be equal to the meter reading multiplied by the ratio of the gas conversion factors.

Example: What is the actual flow rate of Carbon Dioxide through a flowmeter calibrated for Helium, if the meter reading is 96 SCCM?

Solution: Flow of CO_2, $= \dfrac{(\text{meter reading})\ (\text{K for } CO_2)}{\text{K for } H_e}$

$= (96\ \text{SCCM}) * \dfrac{.6933}{1.3820}$

= 48.2 SCCM

5.5.3 Gas Mixtures

If a mixture of gases is used and the percentage by volume of each gas is reasonable constant, a conversion factor for the gas mixture can be obtained.

$$K\ (mix) = \frac{1}{\frac{\bar{V}a}{Ka} + \frac{\bar{V}b}{Kb} + \frac{\bar{V}c}{Kc} + \ldots}$$

Where

$\bar{V}$ (a, b, ….) = percent of gas a, b ….)

K = conversion factor

K can be obtained from the table beginning on page 35 for many gases.

Example: What is the conversion factor for a mixture of 20% Hydrogen, 40% Argon, and 40% Oxygen?

Solution:
$$= \frac{1}{\frac{\bar{V}a}{Ka} + \frac{\bar{V}b}{Kb} + \frac{\bar{V}c}{Kc} + \ldots}$$

$$= \frac{1}{\frac{.2}{1.01} + \frac{.4}{1.41} + \frac{.4}{.96}}$$

$$= 1.11$$

5.6 Output Signal:

The two output terminals on the back of the power supply provide a 0-5 VDC signal for recording or operating auxiliary equipment such as flow controllers or converters. The output signal is linear with respect to mass flow and has sensitivity equal to the rated full-scale flow rate divided by 5.00 VDC.

Example: (A) What is the output sensitivity of HS-1KS?

(B) What is the flow rate for a 2.71 volt output?

Solution:	(A)	Sensitivity	=	$\frac{\text{rated flow}}{\text{Rated output}}$
			=	$\frac{\text{1000 SCCM}}{\text{5.00 VDC}}$
			=	200 SCCM/VDC
	(B)	Mass Flow	=	output X sensitivity
			=	2.71v X 200 SCCM/VDC
			=	542 SCCM

5.7 Accuracy:

The accuracy of the flow indication is +/- 1% of full scale, with the exception of the U-Series transducer where the accuracy is +/- 3% of full scale.

5.8 Repeatability:

The repeatability over a six-month period is +/- ½% of full scale if the flowmeter is operating normally in a clean, dry system. Under reasonable constant conditions, a repeatability of +/- 1 to +/- 2% of INDICATION can be expected on a day-to-day basis.

5.9 Over-range:

The flowmeter has an output signal which is directly proportional to mass flow and linear to +/- of full scale from zero flow to the normal full-scale flowrate.

The flowmeter can be used to measure flow rates higher than the rated maximum flow, but the output signal normally becomes non-linear above 5 volts d-c. A calibration curve for voltage vs. flow can be made for outputs up to 10 volts d-c. At some point above 10 volts d-c the output will no longer increase as the flow increases. The flow rate required to produce this condition is several times the normal full-scale flow rate. Once flow is reduced to the proper level, the flow meter will again indicate mass flow currectly. The flowmeter will not be damaged by excessive flow rates as long as the pressure in the line does not exceed the pressure rating for the transducer.

SECTION 6

Pressure Effects

6.0 PRESSURE EFFECTS

6.1 Standard Transducers:

The Hastings Linear Mass Flowmeter can measure mass flow accurately without corrections for a variation in line pressure from one psia ($\cong$ .068 ATM) to 250 psig ($\cong$ 18 ATMS.) Mass flow indications are possible with downstream pressures as low as .03 psia ($\cong$ .002 ATM), but the upstream must be much higher because of the increase in pressure drop across the transducer (see Section 8.0).

6.2 Low Pressure Drop Transducers:

The low pressure drop Mass Flowmeter (using U-Series transducers) can measure flow accuratley from .03 psia ($\cong$ .002 ATM) to 15 psig ($\cong$ 2 ATMS). The transducer is rated for a maximum pressure of 250 psig ($\cong$ 18 ATMS). Mass flow indications are possible with downstream pressure as low as .1 Torr with upstream pressures of less than 30 Torr. This flowmeter has been successful for many years in measuring uranium hexafluoride flowrate under vacuum conditions, and has also been useful in measuring vacuum pumping speeds and in atmospheric sampling trains.

6.3 High Pressure Transducers (Optional):

Hastings transducers having a P suffix have been pressure tested to 1500 psig using dry nitrogen gas. The transducer was cycled between 0 and 1500 psig for two periods with a minimum of 5 minutes each, and held at the pressure for a combined test period of 10 minutes. It was then leak tested on a Helium Leak Detector where a leak rate of no more than 3 X 10^{-6} SCCS was required.

The flowmeter has been designed and tested as described above for line pressure up to 1500 psig under normal usage. High pressure gas is always potentially dangerous and we strongly urge that extreme caution be taken in locating, installing, and operating this equipment.

7.0 TEMPERATURE EFFECTS

7.1 Ambient Temperatures:

7.1.1 Transducer

In order to maintain the accuracy of the flowmeter with changes in ambient temperature, it is necessary to keep the temperature of the transducer between 10° C and 50° C. (The temperature of the base is normally about 10° C above ambient due to internal heat.) There are two ¼"-20 bolt holes in the bottom of the transducer to facilitate mounting the transducer to an external heat sink. Since some of the temperature shift results in a slight zero offset, better results are obtained if the flowmeter is re-zeroed at the operating temperature.

7.1.2 Power Supply

The NALL-type power supply can be operated over an ambient temperature range of 0° C to 40° C without causing a calibration shift of more than +/- 1% of full scale. Since this error is primarily a zero shift, it can be eliminated by adjusting the flowmeter ZERO potentiometer at the given operating temperature.

7.2 Gas Temperature

No corrections for gas temperature between 0° C and 100° C are necessary for the small ranges, but some correction may be necessary for higher ranges. Part of the error at high ranges is transitory, and in most cases will be reduced when the transducer temperature and gas temperature reach an equilibrium condition. Gas flow at temperatures between -50°C and + 200° C can often be measured, but require recalibration by the customer at operating conditions. Consult the factory for further details.

When using the NALL – or NALLL –P Series flowmeter with a Laminar Flow Element, it is recommended that both the Laminar Flow Element and the HS-10S (or HS-10M) transducer operate at the same temperature.

The Hastings Linear Mass flowmeter measures GAS flow. DO NOT let the temperature and/or pressure of the gas reach a point that would cause the gas to change to a liquid state, or erroneous indications will result.

Differential Pressure

8.1 TYPICAL PRESSURE DROPS

The differential pressure drop (DP) accross the Hastings HS-Series Mass Flow Transducer can vary between 0.50” H_2O depending upon the transducer’s range. Other pressure drops are lsited below and all are based upon full-scalle flow rates of air at 0°C and 760 Torr.

OTHER TYPICAL PRESSURE DROPS

TRANSDUCER TYPE		DP-(“H_2O) @ F.S. Flow
L-5S/HS-10S, L-5M/HS-10M	....	4.0 – 4.9
L-10S/HS-10S, L-10M/HS-10M	....	3.2 – 3.9
L-25S/HS-10S, L-25M/HS-10M	....	5.9 – 6.3
L-50SF/HS-10S, L-50MF/HS-10M	....	5.0 – 5.2
L-100SF/HS-10S, L-100MF/HS-10M	....	6.0 – 6.8
L-200SF/HS-10S, L-200MF/HS-10M	....	4.3 – 5.3
L-500SF/HS-10S, L-500MF/HS-10M	....	5.9 – 7.0
U-TYPE TRANSDUCERS < 1 Torr		< .07” H_2O @ ATM pressure, @ 30 Torr pressure

8.2 CHANGES IN DP WITH CHANGES IN LINE PRESSURE

The typical differential pressure drops listed in the table above are for operation at atmospheric pressure. As the line pressure changes, the differential pressure drop for the same flow rate will also change.

8.2.1 Increase in Line Pressure

The differential pressure drop across the transducer will decrease proportionately as the absolute line pressure increases as stated in the following equation:

$$DP = DP(@STP)\,\frac{\text{Pressure (STD)}}{\text{Pressure (ACT)}}$$

where DP = Transducer differential pressure at 0°C and 760 Torr

Pressure (STD) = 14.7 psia

Pressure (ACT) = 14.7 psia + line pressure

8.2.2 Decrease in Line Pressure

The relationship stated in Section 8.2.1 also shows that DP increases proportionally as absolute line pressure decreases. This situation is true until the DP becomes a significant part of the total absolute line pressure. When this occurs, the relationship becomes more complex but the effect is still the same. The change in DP does not affect the accuracy of the mass flow indications, but causes a change in the minimum upstream pressure necessary to force a given amount of flow through the transducer.

8.3 DP Increase Due to Fouling of the Transducer:

A DP measurement across the transducer can often provide a good indication of fouling inside the transducer. The values given in the Table on the preceding page are typical and may vary as much as 50% for any given model. However, an increase in DP of two or three times the typical value is definitely an indication of fouling. When checking for changes in DP, the flowmeter should be in operation at or near standard conditions of 0°C and 760 Torr in order to relate the measured DP to those listed in the Table. If there is an indication of fouling, refer to Section 10.1.

9.0 CALIBRATION PROCEDURES

The Hastings Mass Flowmeter has been carefully inspected and calibrated at the factory before shipment and will give long, reliable service. Calibration is stable, and recalibration is seldom necessary under normal operating conditions; however, to maintain optimum accuracy it is advisable to check calibration on an annual basis. The unit may be returned to the factory for this purpose, but if that is undesirable, the following calibration procedure may be of assistance:

1. Connect the power supply to the proper power source (Section 3.4).

2. Turn the power supply "ON" and allow 30 minutes for warm-up.

3. Set the "electrical zero" (Section 3.5).

4. Connect the inlet side of the transducer through a metering valve, to a well-regulated air source and the outlet to a reliable flow reference such as the Hastings Mini-Flo Calibrator.

5. Check transducer heating voltage as outlined in Section 10.2.1.

6. During normal calibration, a flowmeter is spanned at 80% of full scale to obtain best average linearity.

Example: A 50 SCCM flowmeter with 0-5 VDC output at the binding posts is to be calibrated. If a reference flow standard is set at a 40 SCCM flow rate, the flowmeter should indicate 80% (.80 X 50 SCCM = 40 SCCM) of full scale. At this flow rate, the voltage at the binding posts should read 4 VDC (80% X 5 VDC).

CAUTION: Most flow standards are volumetric devices and must be corrected for temperature and pressure to standard conditions of 0oC and 760 Torr. This correction amounts to several percent at normal room temperatures and pressures and should not be neglected.

7. If the flowmeter does not agree with the reference flow standard, it is first necessary to correct the output at the binding posts. This is done by making a small adjustment to the "GAIN" potentiometer R-30, located on the circuit board inside the power supply. This adjustment will also produce a change in the meter indication.

8. If the meter reading (flow) does not correspond with the binding post's output (voltage), make a small adjustment to the "METER" trim potentiometer R-32, located on the circuit board inside the power supply. This correction has no effect on the output voltage.

9. PC-581A Board Only: Refer to Figure 9.1. Do not change the dipswitch (S2) settings. These settings are factory pre-set and should only need changing if there is a change in the transducer or the units of calibration. Switches 1, 2, & 3 change gain and 5, 6, 7, & 8 change the meter range to engineering units. The number 4 position should remain closed.

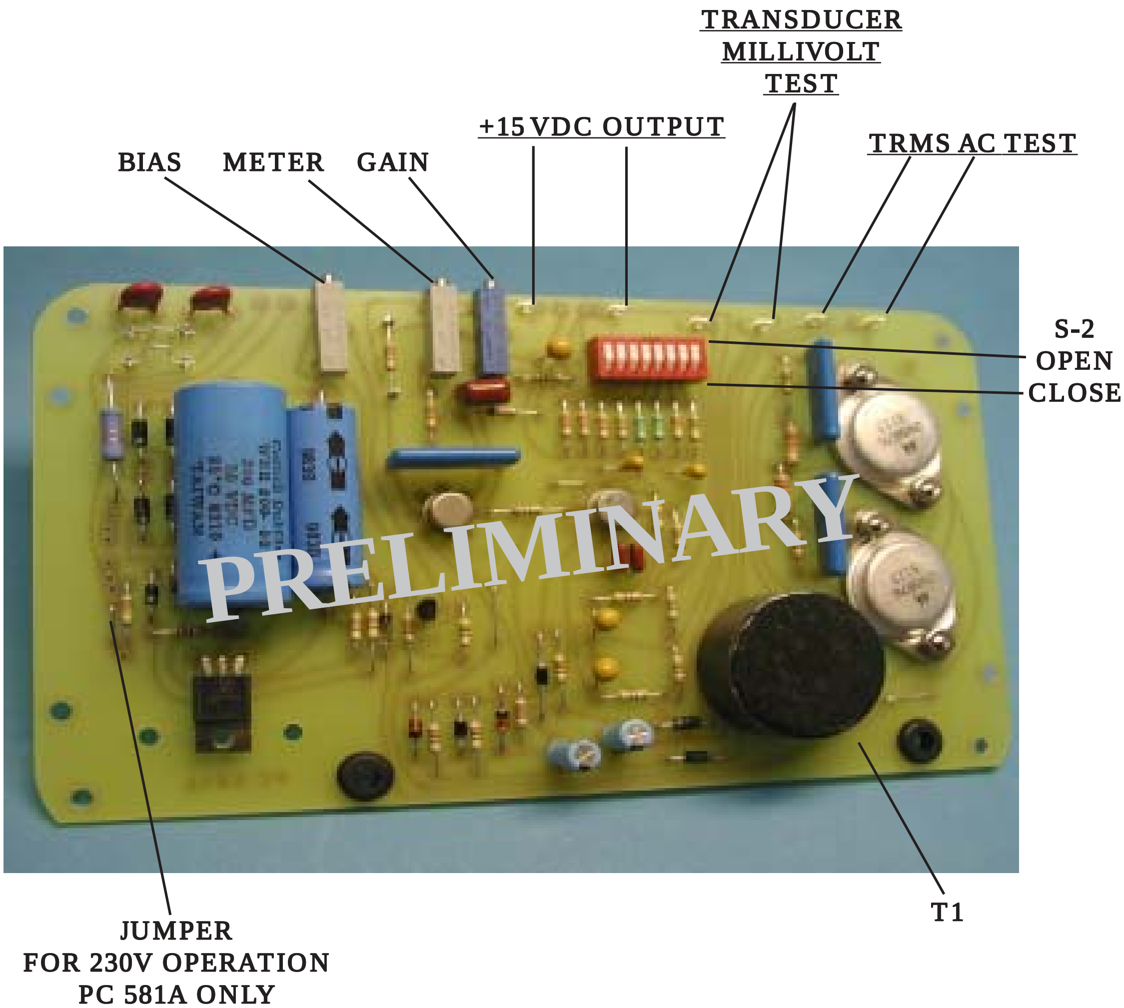


fig 9.1

PC 851A

SECTION 10

Maintenance

10.1 Transducers:

10.1.1 Cleaning

With proper care in installing and use, the transducer will require little or no maintenance. Should the small passages in the transducer become partially clogged, they can be cleaned with any suitable solvent such as acetone, vythene, etc. and/or blown out with clean air under moderate pressure (up to 50 psig).

NOTE: *If solvents are used for cleaning the transducer, sporadic indications may occur when it is returned to service due to residual moisture in the passages of the transducer. Time should be allowed for the liquid solvent to evaporate.*

10.1.2 Damage to the Transducer

The transducer can be checked for internal electrical damage by disconnecting the cable and using an ohm-meter to measure resistances at the 6-pin connector. Internal repairs to the transducer are not recommended and should only be done at the factory. Attempting to remove the transducer cover or the nut on the connector may result in irrepairable damage to the transducer. The table below is for determining whether or not some damage has occurred and **IS NOT** to be used as a guide for repairs.

TRANSDUCER CONTINUITY CHECK

PIN	TO PIN	Resistance	Function
A	D	< 1	Coil Check
B	C	< 5	TC Check
B	E	< 20	TC Check
F	BASE	0	GND

10.2 Power Supply:

NALL and NALL-P power supplies are very stable and should require little or no maintenance. An occasional check of the electrical zero is recommended but drift will be small under normal operating conditions.

10.2.1 Power Supply Troubleshooting

If a problem does occur, the transducer heating voltage and the transducer output can be checked (refer to Figure 9.1). To check the heating voltage, the flowmeter must be connected to the transducer and a true R.M.S. voltmeter must be used. With the TRMS voltmeter connected between test points D and A (TRMS AC test), the voltage should be 16.00 TRMS VAC +/- 0.1 VAC (and can be adjusted by the BIAS pot, R6). The transducer output is measured between test points BC and E (millivolt test) using a DC millivolt meter. This output will vary as flow through the transducer varies. At full scale flow for the transducer, the millivolt meter should read between 0.75 and 7 millivolts DC, depending on the individual transducer. This signal is amplified to produce the flowmeter output.

If it is necessary to return the flowmeter for repair, please return the transducer, power supply, and cable to Teledyne Hastings-Raydist with a detailed explanation of the problem. Use the Service Repair form on page 35. This will help to ensure prompt, reliable service.

Options and Accessories

11.0 OPTIONS AND ACCESSORIES

11.1 Double Point Relay Flowmeter/Alarm (DNALL-P):

The Hastings Flowmeter/Alarm is a complete Linear Mass Flowmeter with all of its characteristics and ranges. It also includes two adjustable HI-LO set points which can be read on the digital indicator. When the flow rate exceeds the pre-set LO alarm point, the LO relay is energized; then its normally closed (NC) contact opens and the normally open (NO) contact closes. This sequence also occurs when the flow rate exceeds the pre-set HI alarm point. The SPDT relays de-energize and return to their normal state when the flow rate drops below the pre-set alarm points. The relays are rated 5 amps @ 115 VAC.

11.2 Totalizers (TNALL-P):

11.2.1 Descriptions

The Hastings Mass Flow Totalizer is an electronic/mechanical device which, when used in conjunction

a. Specifications: (For Totalizer Only)

- Accuracy: 25°C and 115 ± 15 VAC ± ½% F. S.
- Count Rate: 5, 10, 50 & 100 Counts/Min. @ F. S. Flow –selectable by use of the front panel switch.
- Power: 115 volts AC 50-60 Hz, 10 watts.

b. Cicuits

The circuit for the totalizer is a voltage to frequency converter which produces a pulse rate linearlt proportional to the 0-5 volts DC input signal. The pulse rate is set by the factory on standard units for 5, 10, 50, and 100 counts/min. Any of the four ranges can be selected with the Range Selector switch on the front panel or by changing a jumper on the back panel on some models. Normally ranges are 5 cpm or 50 cpm for a 5, 50, 500, 5K, or 50K SCCM range. 10 cpm are used for a 10, 100, 1K, or 10K SCCM range. Other count rates up to 1000 counts/min. are available on special order.

Special count rates are optional when the range of the flowmeter does not correspond to the factor of 5 or 10.

c. Counter:

The pulses from the totalizer circuit are accumulated by the six-digit electro-mechanical counter. The counter recycles automatically at 999,999 or can be manually reset to zero at any time.

11.2.2 Mounting

The Hastings Mass Flow Totalizer is normally built into a NIM style Hastings Mass Flowmeter power supply. The meter is designated by the prefix T.

11.2.3 Totalizer Sensitivity

The totalizer count rate varies in direct proportion to flowmeter output variations. Therefore, the total number of counts over a period of time can be realted to the total flow for that period by determining the sensitivity of the flowmeter/totalizer combination. The sensitivity is the full-scale count rate of the totalizer.

Example: A TNALL-P Flowmeter with an HS-10S transducer is used with the Range Selector set for 100 cpm over a period of 7 hours, and a total of 13,500 counts accumulate on the counter.

a) What is the sensitivity of the totalizer?

b) What is the total flow indicated by the 13,500 count?

c) What is the average flow rate over the 7 hour period?

Solution: a) The full scale flow rate for the TNALL-P/HS-10S is 10 SCCM. The full-scale count rate for the totalizer is 100 counts per minute.

$$\text{Sensitivity} = \frac{\text{F. S. flowrate}}{\text{F. S. countrate}}$$

$$= \frac{10 \text{ std. cm}^3\text{/min.}}{100 \text{ counts/min.}}$$

b) The total flow indicated by 13,500 counts is:

Total flow = total counts X sensitivity

= 13,500 counts X 0.1 std cm^3/min.

= 1350 std cm^3

c) The average flow rate over the 7 hour period is the total flow divided by the time:

$$\text{Average Flow Rate} = \frac{\text{Total Flow}}{\text{Time}}$$

$$= \frac{1350 \text{ std cm}^3}{7 \text{ hrs X } 60 \text{ min/hr}}$$

$$= \frac{1350 \text{ std cm}^3}{420 \text{ min.}}$$

= 3.2 std cm^3/min.

If a special gas is used with the flowmeter (other than that for which it was originally calibrated), refer to Section 5.5 to determine the new full-scale flow rate for the special gas. Once the full-scale rate for the special gas is obtained, it may be used with the equations above to determine the sensitivity of the totalizer in std. cm^3/count.

11.2.4 Maintenance

The totalizer is all solid-state and is designed for a long life expectancy and no maintenance is normally required. Should the totalizer or counter need repair, return them to Teledyne Hastings with a statement describing the problem; use the form on page 35.

11.3 Chassis Model (NALL-C):

Hastings Chassis Linear Mass Flowmeters are designed for installations where the electronic circuits are remotely mounted from both the transducer and readout. It is particularly useful in applications where the meter must be located long distances from the transducer. Thus, the transducer cable is kept short, and the meter may be located long distances from the Chassis without concern for cable losses. Also, panel space is reduced to that of the meter only. The Chassis is designated by adding the suffix "C" to the Cabinet Model number; NALL becomes NALL-C.

11.4 Current Converter (NAll-P/CC):

A 4-20 mA current converter is an option available with the Hastings Mass Flowmeter. The Hastings 4-20 mA may be built into a flowmeter package or supplied as a separate unit. The converter produces a 4-20 mA current signal from the 0-5 VDC output of the flowmeter.

Gas Correction Factors

12.0 Gas Correction Factors

The gas conversion factors (GCF's) provided by Hastings Instruments (HI) fall into five basic accuracy domains that, to a large extent, are dependent on the method by which they are found. The following table summarizes the different methods used to determine the GCF's. The table lists the methods in decreasing order of the degree of accuracy that may be achieved when applying a conversion factor.

Methods Used to Determine Gas Correction Factors

1. Determined empirically at Hastings Instruments
2. Calculated From NIST tables
3. Calculated using the virial coefficients of independent investigators' empirical data using both temperature and pressure as variables.
4. Calculated from virial coefficients using temperature only.
5. Calculated from specific heat data at 0° C and 1 atmosphere

1. The most accurate method is by direct measurement. Gases that can be handled safely, inert gases, gases common in the atmosphere, etc., can be run through a standard flow meter and the GCF determined empirically.

2. The National Institute of Standards and Technology (NIST) maintains tables of thermodynamic properties of certain fluids. Using these tables, one may look up the necessary thermophysical property and calculate the GCF with the same degree of accuracy as going directly to the referenced investigator.

3 and 4. Many gases that have been investigated sufficiently by other researchers, can have their molar specific heat (C'_p) calculated. The gas correction factor is then calculated using the following ratio.

$$GCF = \frac{C'_{pN2}}{C'_{pGasX}}$$

GCF's calculated in this manner have been found to agree with the empirically determined GCF's within a few tenths of a percent. Data from investigations where pressure, as well as temperature, usually supply a higher degree of accuracy in their predictions.

5. For rare, expensive gases or gases requiring special handling due to safety concerns, one may look up specific heat properties in a variety of texts on the subject. Usually, data found in this manner applies only in the ideal gas case. This method yields GCF's for ideal gases but as the complexity of the gas increases, its behavior departs from that of an ideal gas. Hence the inaccuracy of the GCF increases.

Hastings Instruments continually searches for better estimates of the GCF's of the more complex gases and regularly updates the list.

Most Hastings flow meters and controllers are calibrated using nitrogen. The correction factors published by Hastings are meant to be applied to these meters. To apply the GCF's, simply multiply the gas flow reading and the GCF for the process gas in use. For example, to calculate the actual flow of argon passing through a nitrogen-calibrated meter that reads 20 sccm, multiply the reading and the GCF for argon.

$$20 \times 1.3978 = 27.956$$

Conversely, to determine what reading to set a nitrogen-calibrated meter in order to get a desired flow rate of a process gas other than nitrogen, you divide the desired rate by the GCF. For example, to get a desired flow of 20 sccm of argon flowing through the meter, divide 20 sccm by 1.3978.

$$20 / 1.3978 = 14.308$$

That is, you set the meter to read 14.308 sccm.

Some meters, specifically the high flow meters, are calibrated in air. The flow readings must be corrected for the case where a gas other than air is flowing through the meter. In addition, there must be a correction for the difference in the GCF from nitrogen to air. In this case, multiply the reading and the ratio of the process gas' GCF to the GCF of the calibration gas. For example, a meter calibrated in air is being used to measure the flow of propane. The reading from the meter is multiplied by the GCF for propane divided by the GCF of air.

$$20 * (0.3499/1.0015) = 6.9875$$

To calculate a target setting (20 sccm) to achieve a desired flow rate of propane using a meter calibrated to air, invert the ratio above and multiply.

$$20 * (1.0015/0.3499) = 57.2449$$

Rec #	Gas	Symbol	GCF	Derived	Density (g/L) 25° C / 1 atm	Density (g/L)* 0° C / 1 atm
1	Acetic Acid	$C_2H_4F_2$	0.4164	4	2.700	2.947
2	Acetic Acid, Anhydride	$C_4H_6O_3$	0.2586	4	4.173	4.555
3	Acetone	C_3H_6O	0.3564	4	2.374	2.591
4	Acetonitryl	C_2H_3N	0.5186	4	1.678	1.832
5	Acetylene	C_2H_2	0.6262	4	1.064	1.162
6	Air	Air	0.9971	1	1.185	1.293
7	Allene	C_3H_4	0.4522	4	1.638	1.787
8	Ammonia	NH_3	0.7810	2	0.696	0.760
9	Argon	Ar	1.4119	1	1.633	1.782
10	Arsine	AsH_3	0.7592	5	3.186	3.478
11	Benzene	C_6H_6	0.3067	4	3.193	3.485
12	Boron Trichloride	BCl_3	0.4426	4	4.789	5.228
13	Boron Triflouride	BF_3	0.5438	4	2.772	3.025
14	Bromine	Br_2	0.8009	4	6.532	7.130
15	Bromochlorodifluoromethane	CBrClF2	0.3688	4	6.759	7.378
16	Bromodifluoromethane	$CHBrF_2$	0.4651	4	5.351	5.841
17	Bromotrifluormethane	$CBrF_3$	0.3948	4	6.759	7.378
18	Butane	C_4H_{10}	0.2628	2	6.087	6.644
19	Butanol	$C_4H_{10}O$	0.2412	4	3.030	3.307
20	Butene	C_4H_8	0.3063	4	2.293	2.503
21	Carbon Dioxide	CO_2	0.6933	1	2.293	2.503
22	Carbon Disulfide	CS_2	0.6165	4	1.799	1.964
23	Carbon Monoxide	CO	1.0013	4	3.112	3.397

Rec #	Gas	Symbol	GCF	Derived	Density (g/L)	Density (g/L)*
24	Carbon Tetrachloride	CCl_4	0.3336	4	6.287	6.863
25	Carbonyl Sulfide	COS	0.6686	4	1.145	1.250
26	Chlorine	Cl_2	0.8454	4	2.456	2.680
27	Chlorine Trifluoride	ClF_3	0.4496	5	2.898	3.163
28	Chlorobenzene	C_6H_5Cl	0.2620	4	4.601	5.022
29	Chlorodifluoroethane	$C_2H_3ClF_2$	0.3222	4	4.108	4.484
30	Chloroform	$CHCl_3$	0.4197	4	3.779	4.125
31	Chloropentafluoroethane	C_2ClF_5	0.2440	4	6.314	6.892
32	Chloropropane	C_3H_7Cl	0.3087	4	3.210	3.504
33	Cisbutene	C_4H_8	0.3010	4	2.293	2.503
34	Cyanogen	C_2N_2	0.4927	4	4.270	4.661
35	Cyanogen Chloride	ClCN	0.6486	5	2.127	2.322
36	Cyclobutane	C_4H_8	0.3573	4	2.293	2.503
37	Cyclopropane	C_3H_6	0.4575	4	2.513	2.743
38	Deuterium	H^2_2	1.0003	4	1.720	1.877
39	Diborane	B_2H_6	0.5063	5	0.165	0.180
40	Dibromodifluoromethane	CBr2F2	0.3594	4	8.576	9.361
41	Dichlorofluoromethane	$CHCl_2F$	0.4487	4	4.207	4.592
42	Dichloromethane	CH_2Cl_2	0.5320	4	3.472	3.789
43	Dichloropropane	$C_3H_6Cl_2$	0.2703	4	4.618	5.041
44	Dichlorosilane	H_2SiCl_2	0.4716	5	4.129	4.506
45	Diethyl Amine	$C_4H_{11}N$	0.2261	4	2.989	3.263
46	Diethyl Ether	$C_4H_{10}O$	0.2239	4	3.030	3.307
47	Diethyl Sulfide	$C_4H_{10}S$	0.2260	4	3.686	4.024
48	Difluoroethylene	$C_2H_2F_2$	0.4501	4	2.617	2.857
49	Dimethylamine	C_2H_7N	0.3713	4	1.843	2.011
50	Dimethyl Ether	C_2H_6O	0.4095	4	1.883	2.055
51	Dimethyl Sulfide	C_2H_6S	0.3629	4	2.540	2.772
52	Divinyl	C_4H_6	0.3256	4	2.211	2.413
53	Ethane	C_2H_6	0.4268	2	1.229	1.342
54	Ethane, 1-chloro-1,1,2,2-tetrafluoro-	C_2HClF_4	0.2689	4	5.578	6.089
55	Ethane, 1-chloro-1,2,2,2-tetrafluoro-	C_2HClF_4	0.2723	4	5.578	6.089
56	Ethanol	C_2H_6O	0.4055	4	1.883	2.055
57	Ethylacetylene	C_4H_6	0.3263	4	2.211	2.413
58	Ethyl Amine	C_2H_7N	0.3702	4	1.843	2.011
59	Ethylbenzene	C_8H_{10}	0.2007	4	4.339	4.737
60	Ethyl Bromide	C_2H_5Br	0.4132	4	4.454	4.862
61	Ethyl Chloride	C_2H_5Cl	0.4220	4	2.637	2.878
62	Ethyl Fluoride	C_2H_5F	0.4439	4	1.964	2.144
63	Ethylene	C_2H_4	0.5230	1	1.147	1.252
64	Ethylene Dibromide	$C_2H_4Br_2$	0.3178	4	7.679	8.382
65	Ethylene Dichloride	$C_2H_4Cl_2$	0.3481	4	4.045	4.415
66	Ethylene Oxide	C_2H_4O	0.5322	4	1.801	1.965
67	Ethyleneimine	C_2H_4N	0.4804	4	1.719	1.877
68	Ethylidene Dichloride	$C_2H_4Cl_2$	0.3512	4	4.045	4.415
69	Ethyl Mercaptan	C_2H_6S	0.3660	4	2.540	2.772
70	Fluorine	F_2	0.9119	4	1.553	1.695
71	Formaldehyde	CH_2O	0.7921	4	1.227	1.340
72	Freon 11	CCl_3F	0.3539	4	5.615	6.129
73	Freon 12	CCl_2F_2	0.3716	4	4.942	5.395
74	Freon 13	$CClF_3$	0.3796	4	4.270	4.661
75	Freon 14	CF_4	0.4430	4	3.597	3.926
76	Freon 22	$CHClF_2$	0.4865	4	3.534	3.858
77	Freon 23	CHF_3	0.5291	4	2.862	3.124
78	Freon 114	$C_2Cl_2F_4$	0.2330	4	6.986	7.626
79	Furan	C_4H_4O	0.3901	4	2.783	3.037
80	Helium	He	1.3820	1	0.164	0.179
81	Heptafluoropropane	C_3HF_7	0.1990	4	6.950	7.586
82	Hexamethyldisilazane	$C_6H_{19}NSi_2$	0.1224	4	6.597	7.201
83	Hexamethyldisiloxane	$C_6H_{18}OSi_2$	0.1224	4	6.637	7.245
84	Hexane	C_6H_{14}	0.1832	4	3.522	3.845
85	Hexafluorobenzene	C_6F_6	0.1736	4	7.605	8.301

Rec #	Gas	Symbol	GCF	Derived	Density (g/L)	Density (g/L)*
86	Hexene	C_6H_{12}	0.1922	4	3.440	3.755
87	Hydrazine	N_2H_4	0.5515	4	1.310	1.430
88	Hydrogen	H_2	1.0091	1	0.082	0.090
89	Hydrogen Bromide	HBr	1.0028	4	3.307	3.610
90	Hydrogen Chloride	HCl	1.0034	4	1.490	1.627
91	Hydrogen Cyanide	CHN	0.7778	4	1.105	1.206
92	Hydrogen Fluoride	HF	1.0039	4	0.818	0.893
93	Hydrogen Iodide	HI	0.9997	4	5.228	5.707
94	Hydrogen Selenide	H_2Se	0.8412	5	3.309	3.612
95	Hydrogen Sulfide	H_2S	0.8423	4	1.393	1.521
96	Isobutane	C_4H_{10}	0.2730	2	2.376	2.593
97	Isobutanol	$C_4H_{10}O$	0.2397	4	3.030	3.307
98	Isobutene	C_4H_8	0.2990	4	2.293	2.503
99	Isopentane	C_5H_{12}	0.2181	4	2.949	3.219
100	Isopropyl Alcohol	C_3H_8O	0.2938	4	2.456	2.681
101	Isoxazole	C_3H_3NO	0.4345	4	2.823	3.081
102	Ketene	C_2H_2O	0.5743	4	1.718	1.875
103	Krypton	Kr	1.4042	4	3.425	3.739
104	Methane	CH_4	0.6919	1	0.656	0.716
105	Methanol	CH_4O	0.6176	4	1.310	1.430
106	Methyl Acetate	$C_3H_6O_2$	0.3090	4	3.028	3.305
107	Methyl Acetylene	C_3H_4	0.4437	4	1.638	1.787
108	Methylamine	CH_5N	0.5370	4	1.269	1.386
109	Methyl Bromide	CH_3Br	0.6368	4	3.881	4.236
110	Methyl Chloride	CH_3Cl	0.6649	4	2.064	2.253
111	Methylcyclohexane	C_7H_{14}	0.1859	4	4.013	4.381
112	Methyl Ethyl Amine	C_3H_9N	0.2698	4	2.416	2.637
113	Methyl Ethyl Ether	C_3H_8O	0.2849	4	2.456	2.681
114	Methyl Ethyl Sulfide	C_3H_8S	0.2749	4	3.113	3.398
115	Methyl Fluoride	CH_3F	0.7258	4	1.391	1.518
116	Methyl Formate	$C_2H_4O_2$	0.3983	4	2.455	2.679
117	Methyl Iodide	CH_3I	0.6522	4	5.802	6.333
118	Methyl Mercaptan	CH_4S	0.5417	4	1.966	2.146
119	Methylpentene	C_6H_{12}	0.2042	4	3.440	3.755
120	Methyl Vinyl Ether	C_3H_6O	0.3442	4	2.374	2.591
121	Neon	Ne	1.4043	4	0.825	0.900
122	Nitric Oxide	NO	0.9795	4	1.226	1.339
123	Nitrogen	N_2	1.0000	1	1.145	1.250
124	Nitrogen Dioxide	NO_2	0.7610	4	1.880	2.053
125	Nitrogen Tetroxide	N_2O_4	0.3399	4	3.761	4.105
126	Nitrogen Trifluoride	NF_3	0.5406	5	2.902	3.168
127	Nitromethane	CH_3NO_2	0.4662	4	2.495	2.723
128	Nitrosyl Chloride	NOCl	0.6360	4	2.676	2.920
129	Nitrous Oxide	N_2O	0.7220	1	1.799	1.964
130	n-Pentane	C_5H_{12}	0.2126	4	2.949	3.219
131	Octane	C_8H_{18}	0.1389	4	4.669	5.096
132	Oxygen	O_2	0.9614	1	1.308	1.428
133	Oxygen Difluoride	F_2O	0.6460	4	2.207	2.409
134	Ozone	O_3	0.7029	4	1.962	2.141
135	Pentaborane	B_5H_9	0.1499	5	2.580	2.816
136	Pentane	C_5H_{12}	0.2180	4	2.949	3.219
137	Perchloryl Fluoride	$ClFO_3$	0.4162	4	4.188	4.571
138	Perfluorocyclobutane	C_4F_8	0.1714	4	8.176	8.924
139	Perfluoroethane	C_2F_6	0.2534	4	5.641	6.158
140	Perfluoropropane	C_3F_8	0.1820	4	7.685	8.389
141	Phenol	C_6H_6O	0.2496	4	3.847	4.199
142	Phosgene	$COCl_2$	0.4817	4	4.043	4.413
143	Phosphine	PH_3	0.7859	5	1.390	1.517
144	Phosphorus Trifluoride	PF_3	0.4972	5	3.596	3.925
145	Propane	C_3H_8	0.2939	1	1.802	1.967
146	Propyl Alcohol	C_3H_8O	0.3067	4	2.456	2.681
147	Propyl Amine	C_3H_9N	0.2867	4	2.416	2.637
148	Propylene	C_3H_6	0.4048	2	1.720	1.877

Rec #	Gas	Symbol	GCF	Derived	Density (g/L)	Density (g/L)*
149	Pyradine	C_5H_5N	0.3232	4	3.233	3.529
150	R32	CH_2F_2	0.6207	2	2.126	2.321
151	R123	$C_2HCl_2F_3$	0.2586	2	6.251	6.823
152	R123A	$C_2HCl_2F_3$	0.2702	4	6.251	6.823
153	R125	C_2HF_5	0.2831	2	4.906	5.355
154	R134	$C_2H_2F_4$	0.3001	4	4.170	4.552
155	R134a	$C_2H_2F_4$	0.3115	2	4.170	4.552
156	R143	$C_2H_3F_3$	0.3457	4	3.435	3.750
157	R143A	$C_2H_3F_3$	0.3401	4	3.435	3.750
158	R152A	$C_2H_4F_2$	0.3885	4	2.700	2.947
159	R218	C_3F_8	0.1820	4	7.685	8.389
160	R1416	$C_2H_3Cl_2F$	0.3052	4	4.780	5.218
161	Radon	Rn	1.4042	5	9.074	9.905
162	Sec-butanol	$C_4H_{10}O$	0.2331	4	3.030	3.307
163	Silane	SiH_4	0.6809	5	1.313	1.433
164	Silicone Tetrafluoride	SiF_4	0.3896	5	4.254	4.644
165	Sulfur Dioxide	SO_2	0.6881	4	2.619	2.858
166	Sulfur Hexafluoride	SF_6	0.2502	1	5.970	6.516
167	Sulfur Tetrafluoride	SF_4	0.3758	4	4.417	4.821
168	Sulfur Trifluoride	SF_3	0.0437	4	3.640	3.974
169	Sulfur Trioxide	SO_3	0.5404	4	3.273	3.572
170	Tetrachloroethylene	C_2Cl_4	0.2929	4	6.778	7.399
171	Tetrafluoroethylene	C_2F_4	0.3400	4	4.088	4.462
172	Tetrahydrofuran	C_4H_8O	0.3282	4	2.947	3.217
173	Tert-butanol	$C_4H_{10}O$	0.2303	4	3.030	3.307
174	Thiophene	C_4H_4S	0.3547	4	2.783	3.037
175	Toluene	C_7H_8	0.2455	4	3.766	4.111
176	Transbutene	C_4H_8	0.2061	4	2.293	2.503
177	Trichloroethane	$C_2H_3Cl_3$	0.3138	4	5.453	5.952
178	Trichloroethylene	C_2HCl_4	0.3427	4	6.820	7.444
179	Trichlorotrifluoroethane	$C_2Cl_3F_3$	0.2256	4	7.659	8.360
180	Triethylamine	$C_6H_{15}N$	0.1623	4	4.136	4.515
181	Trimethyl Amine	C_3H_9N	0.2829	4	2.416	2.637
182	Tungsten Hexafluoride	WF_6	0.2453	5	12.174	13.288
183	Uranium Hexafluoride	UF_6	0.1859	4	14.389	15.706
184	Vinyl Bromide	C_2H_3Br	0.4776	4	4.372	4.772
185	Vinyl Chloride	C_2H_3Cl	0.4966	4	2.555	2.788
186	Vinyl Flouride	C_2H_3F	0.5716	5	1.882	2.054
187	Water Vapor	H_2O	0.7992	5	0.742	0.810
188	Xenon	Xe	1.4042	4	5.366	5.858
189	Xylene, m-	C_8H_{10}	0.2041	4	4.339	4.737
190	Xylene, o-	C_8H_{10}	0.1958	4	4.339	4.737
191	Xylene, p-	C_8H_{10}	0.2033	4	4.339	4.737

Warranty

13.1 Warranty Repair Policy

Hastings Instruments warrants this product for a period of one year from the date of shipment to be free from defects in material and workmanship. This warranty does not apply to defects or failures resulting from unauthorized modification, misuse or mishandling of the product. This warranty does not apply to batteries or other expendable parts, nor to damage caused by leaking batteries or any similar occurrence. This warranty does not apply to any instrument which has had a tamper seal removed or broken.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty as to fitness for a particular use. Hastings Instruments shall not be liable for any indirect or consequential damages.

Hastings Instruments, will, at its option, repair, replace or refund the selling price of the product if Hastings Instruments determines, in good faith, that it is defective in materials or workmanship during the warranty period. Defective instruments should be returned to Hastings Instruments, **shipment prepaid,** together with a written statement of the problem and a Return Material Authorization (RMA) number. Please consult the factory for your RMA number before returning any product for repair. Collect freight will not be accepted.

13.2 Non-Warranty Repair Policy

Any product returned for a non-warranty repair must be accompanied by a purchase order, RMA form and a written description of the problem with the instrument. If the repair cost is higher, you will be contacted for authorization before we proceed with any repairs. If you then choose not to have the product repaired, a minimum will be charged to cover the processing and inspection. Please consult the factory for your RMA number before returning any product repair.

TELEDYNE HASTINGS INSTRUMENTS

804 NEWCOMBE AVENUE

HAMPTON, VIRGINIA 23669 U.S.A.

ATTENTION: REPAIR DEPARTMENT

TELEPHONE	(757) 723-6531
	1-800-950-2468
FAX	(757) 723-3925
E MAIL	hastings_instruments@teledyne.com
INTERNET ADDRESS	http://www.hastings-inst.com

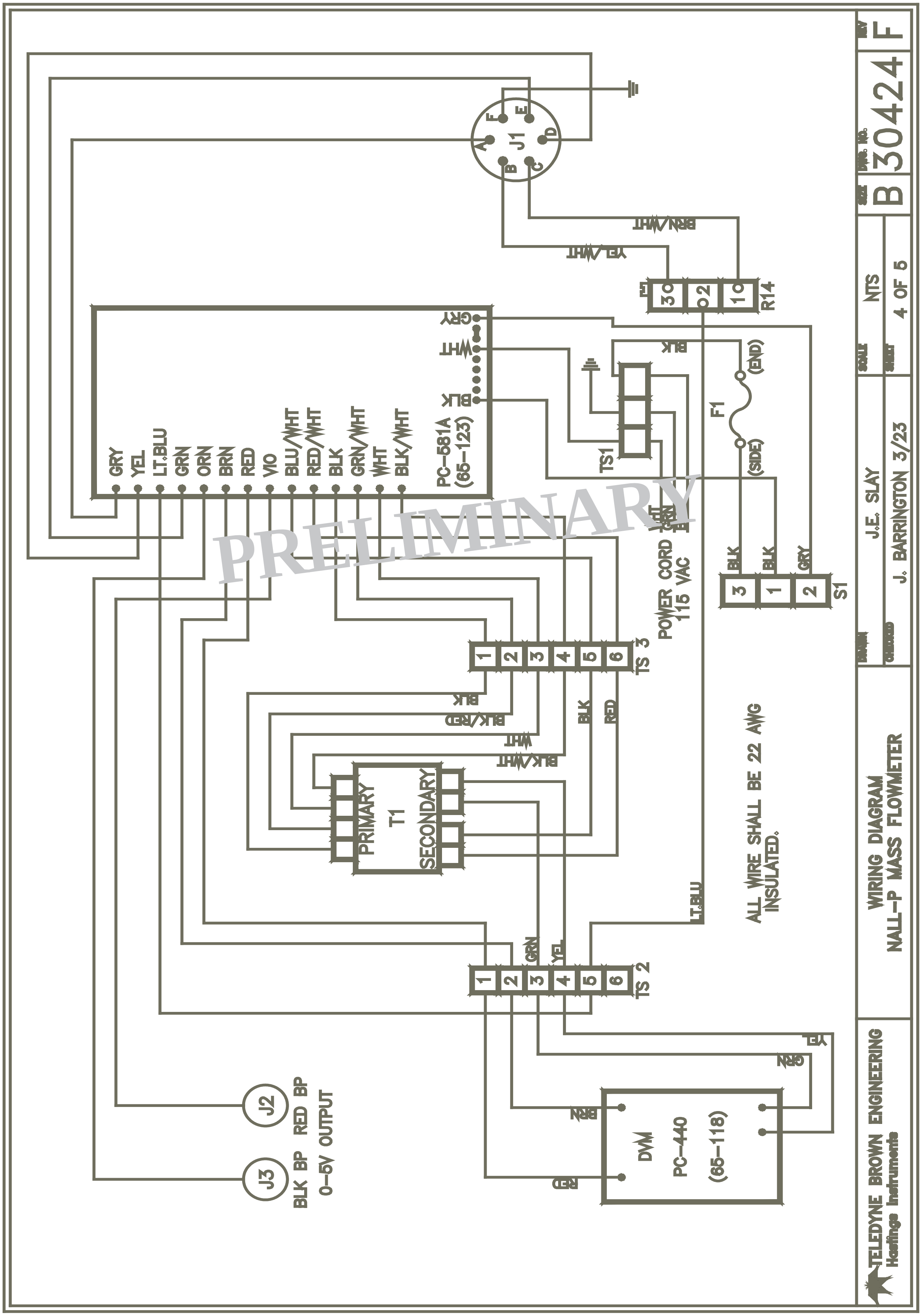
Repair Forms may be obtained from the "Information Request" section of the Hastings Instruments web site.

SECTION 14

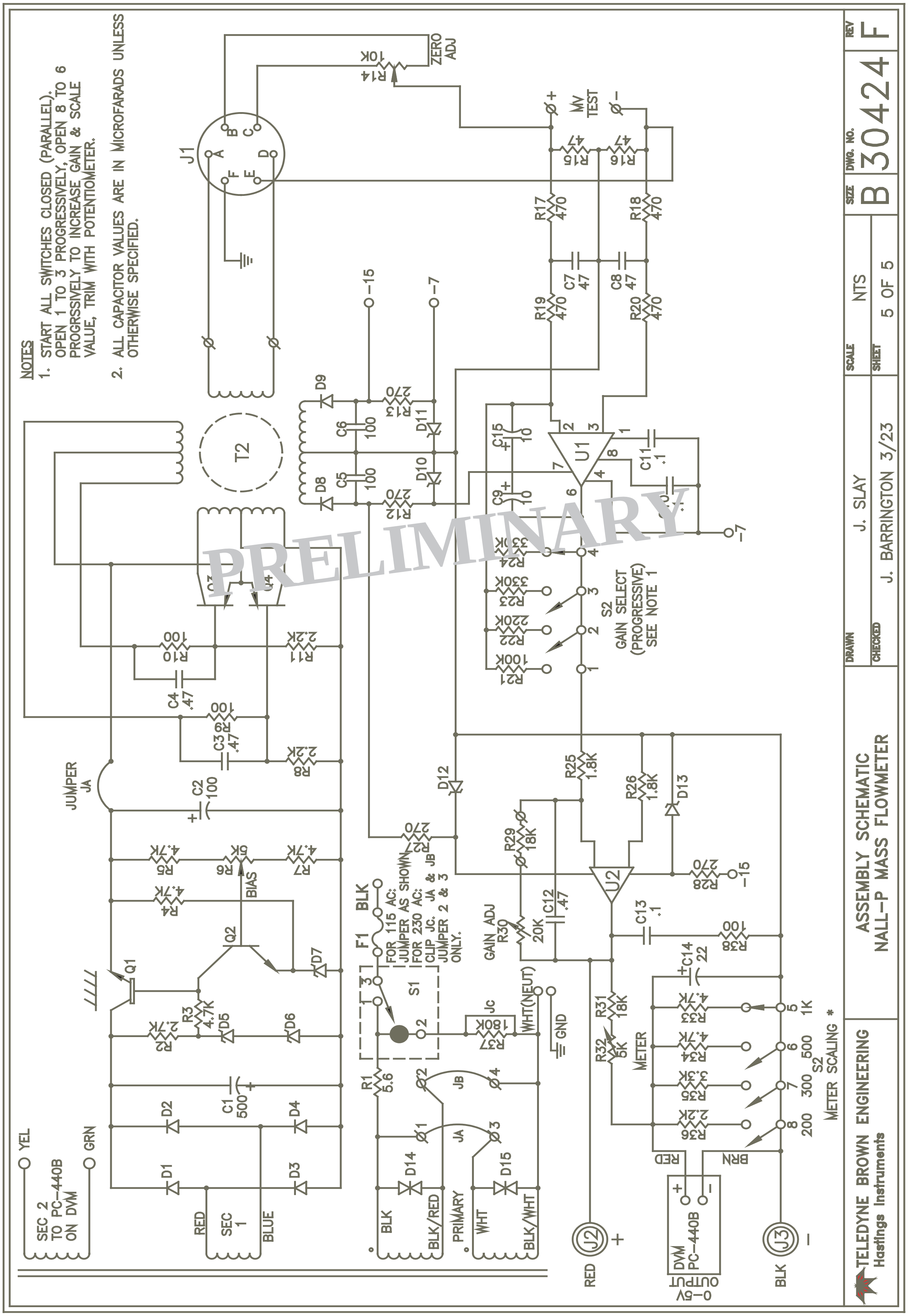
Diagrams and Drawings

14.0 DIAGRAMS AND DRAWINGS

This section contains the schematics, parts, list, and overall assembly drawings. If replacement components are desired, they can be obtained from the factory by referencing the Hastings part number listed on the parts list.



TELEDYNE BROWN ENGINEERING
Hastings Instruments
WIRING DIAGRAM
NALL-P MASS FLOWMETER
J.E. SLAY
J. BARRINGTON 3/23
NTS
4 OF 5
B
30424
F
ALL WIRE SHALL BE 22 AWG
INSULATED.
PC-581A
(65-123)
GRY
YEL
LT.BLU
GRN
ORN
BRN
RED
VIO
BLU/WHT
RED/WHT
BLK
GRN/WHT
WHT
BLK/WHT
J1
A
B
C
D
E
F
YEL/WHT
BRN/WHT
R14
TS1
F1
(END)
(SIDE)
S1
POWER CORD
115 VAC
TS 3
TS 2
T1
PRIMARY
SECONDARY
BLK/RED
DVM
PC-440
(65-118)
J2
J3
RED BP
BLK BP
0-5V OUTPUT
PRELIMINARY


NOTES
1. START ALL SWITCHES CLOSED (PARALLEL). OPEN 1 TO 3 PROGRESSIVELY, OPEN 8 TO 6 PROGRSSIVELY TO INCREASE GAIN & SCALE VALUE, TRIM WITH POTENTIOMETER.
2. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
PRELIMINARY
J1
ZERO ADJ
R14 10K
MV TEST
T2
JUMPER JA
BIAS
F1 BLK
FOR 115 AC: JUMPER AS SHOWN
FOR 230 AC: CLIP JC, JA & JB JUMPER 2 & 3 ONLY.
S1
GAIN ADJ R30 20K
S2 GAIN SELECT (PROGRESSIVE) SEE NOTE 1
S2 METER SCALING *
METER
PRIMARY
SEC 1
SEC 2 TO PC-440B ON DVM
DVM PC-440B
0-5V OUTPUT
RED
BLK
TELEDYNE BROWN ENGINEERING
Hastings Instruments
ASSEMBLY SCHEMATIC
NALL-P MASS FLOWMETER
DRAWN J. SLAY
CHECKED J. BARRINGTON 3/23
SCALE NTS
SHEET 5 OF 5
SIZE B
DWG. NO. 30424
REV F

STOCK NO. 65-123

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
D	REVISED PER ECN #1343	11/19	R. B. M.
E	REVISED PER ECN #1621	06/17/02	T. GRUCHOW
F	REVISED PER ECN #1723	09/23/03	T. GRUCHOW

NOTES:

1. SECURE Q3 & Q4 USING A 4-40 x .38 LG. X-REC PHSS SCREW (2 EACH) INSTALLED FROM FAR SIDE. SECURE SCREW USING 4-40 LOCKWASHER AND NUT ON NEAR SIDE.
2. CLIP OFF PIN 8 OF COMPONENT U2.
3. BEND LEADS OF COMPONENT Q1 AT STEP, WITH METAL SIDE DOWN, LEAVING SPACE FOR THE HEATSINK (#65-408 OR #65-519) BETWEEN COMPONENT Q1 AND THE PC BOARD.

ITEM NO.	QTY REQD	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REF/DWG NO.
20	2		18-02-428	RES, 47 OHM, 1/4W , 5%	R15,16
19	4		18-02-420	RES, 270 OHM, 1/4W , 5%	R12,13,27,28
18	2		18-02-370	RES, 2.2 KOHM, 1/2W	R8,11
17	3		18-02-066	RES, 100 OHM, 1/4W	R9,10,38
16	2		18-02-049	RES, 330 KOHM, 1/4W, 5%	R23,24
15	2		13-01-139	DIODE, 1N-4743A, ZENER	D12,13
14	3		13-01-105	DIODE, 1N-4737	D5,10,11
13	1		13-01-102	DIODE, 1N965B, ZENER	D6
12	1		13-01-080A	DIODE, 1N-823, ZENER	D7
11	2		13-01-076A	DIODE, V1301A1, VAR	D14,15
10	1		11-09-063	CAP, 1uf, 50V	C13
9	2		11-09-062	CAP, .1uf, 50V	C10,11
8	3		11-09-029	CAP, .47uf, 200V	C3,4,12
7	2		11-03-150	CAP, 10uf, 15V	C9,15
6	2		11-03-137	CAP, 100uf, 25V	C5,6
5	2		11-03-132	CAP, 47uf, 6V	C7,8
4	1		11-03-119	CAP, 500uf, 50V	C1
3	1		11-03-118A	CAP, 22uf, 16V	C14
2	1		11-03-106	CAP, 100uf, 50V	C2
1	1		26-04-581A	PC-581A, BOARD	30422

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:

FRACTIONS	DECIMALS	ANGLES
± 1/64	.XX± .01 .XXX± .005	± 2°

TELEDYNE HASTINGS INSTRUMENTS

MECHANICAL DETAIL
PC - 581A

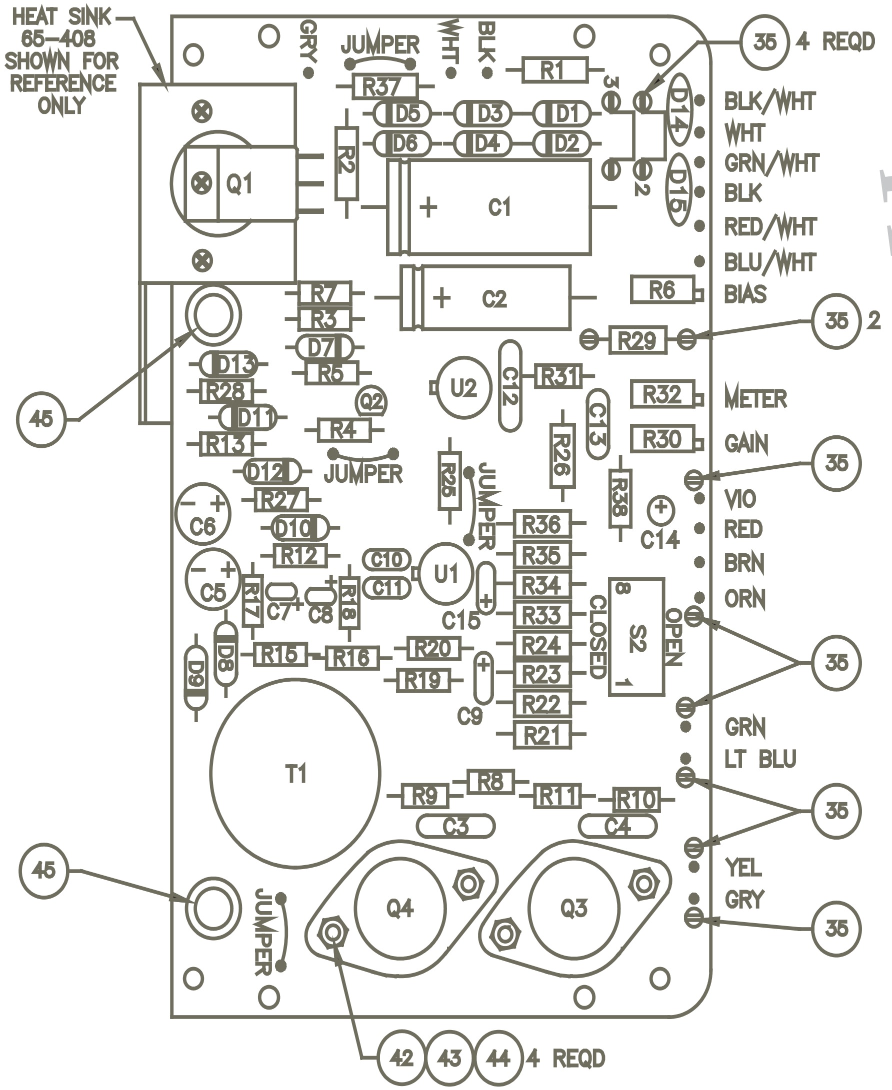
DRAWN	M. SIMMONS	04/98
CHECKED	B. MILLER	11/99

SIZE B | FSCM NO. | DWG NO. 30423 | REV F
SCALE NONE | SHEET 1 of 3

B30423F

09/17/03

A. ARAIZA



ITEM NO.	QTY REQD	FROM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REF/DWG NO.
46	1		65-139	TRANSFORMER, TOROID	T1
45	2		28-01-002	7/16 INCH GROMMET-BLACK	
44	4		28-22-059	WASHER, LOCK, SPLIT, #4 SS	
43	4		28-16-005	HEX NUT, 4-40 SS	
42	4		28-22-055	SCREW, PAN HD, 4-40 X .375L PHSS	
41	1		56-02-048	IC, ICL-7650	U1
40	1		56-02-014	IC, MC1741CG	U2
39	1		51-06-006	TRANSISTOR, 2N3904	Q2
38	2		51-03-049	TRANSISTOR, 2N5876	Q3,4
37	1		51-03-055	TRANSISTOR TIP 120 REG	Q1
36	6		36-01-031	DIODE 1N 2071, 600V	D1,2,3,4,8,9
35	12		28-10-102	SPLIT TERMINALS	
34	1		20-05-067	SWITCH, DIP, 8 POSITION	S2
33	1		19-05-023	POT, 20 KOHM	R30
32	2		19-05-016	POT, 5 KOHM	R6,32
31	1		18-02-536	RES, 5.6 OHM, 1W	R1
30	1		18-02-463	RES, 220 KOHM, 1/4W, 5%	R22
29	1		18-02-462	RES, 180000 OHM, 1/4W, 5%	R37
28	1		18-02-460	RES, 100 KOHM, 1/4W, 5%	R21
27	2		18-02-451	RES, 18000 OHM, 1/4W, 5%	R29,31
26	6		18-02-445	RES, 4.7 KOHM, 1/4W, 5%	R3,4,5,7,33,34
25	1		18-02-443	RES, 3.3 KOHM, 1/4W, 5%	R35
24	1		18-02-442	RES, 2700 OHM, 1/4W, 5%	R2
23	1		18-02-441	RES, 2200 OHM, 1/4W, 5%	R36
22	2		18-02-440	RES, 1800 OHM, 1/4W, 5%	R25,26
21	4		18-02-435	RES, 470 OHM, 1/4W, 5%	R17,18,19,20

PARTS LIST

TELEDYNE HASTINGS INSTRUMENTS
HAMPTON, VIRGINIA USA

ASSY DIAGRAM, PC-581A

DRAWN	DATE	SIZE	FSCM NO.	DWG NO.	REV
M. SIMMONS	04/98	B		30423	F
CHECKED B. MILLER	11/99	SCALE NONE		SHEET 2 of 3	

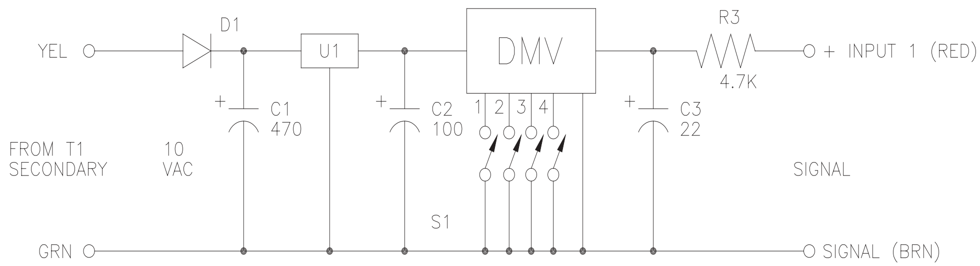
PRELIMINARY

B30423F

09/17/03

A. ARAIZA

REV	DESCRIPTION	DATE	APPROVED
C	REVISION PER DWO #109	5/22/91	JMC
D	REVISION PER ECN #1052		

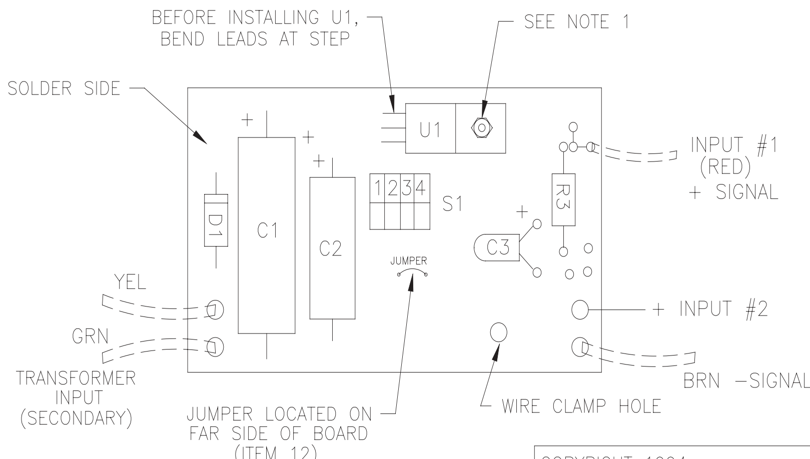


SCHEMATIC PC-440B & PC-440BW

S-1 ~ ALL OPEN = NO DECIMAL
1 CLOSED XX.X
2 CLOSED XXX.
3 CLOSED X.XX
4 NO CONNECTION

NOTES:

1. SECURE U1 USING A 4-40 PH, X-REC, SS SCREW INSTALLED FROM FAR SIDE. SECURE SCREW USING 4-40 LOCKWASHER AND NUT ON NEAR SIDE.
2. ASSEMBLY 65-346 IS IDENTICAL TO ASSEMBLY 65-118 EXCEPT SWITCH S1 (20-05-068) IS OMITTED.
3. ALL COMPONENTS ARE MOUNTED ON THE SOLDER SIDE OF THE CIRCUIT CARD WITH THE EXCEPTION OF THE JUMPER (ITEM 12) WHICH IS INSTALLED ON THE OPPOSITE SIDE.



PARTS LIST

ITEM NO.	QTY REQD	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	REF/DWG NO.
12	1		–	BUS WIRE	
11	1		–	LOCKWASHER, SPLIT, #4, SS	CRES
10	1		–	NUT, 4-40, SS	CRES
9	1		–	SCREW, 4-40 X .25 LG, SS PH, X-REC	CRES
8	1		56-02-020	IC, UGH 7805-393, 5V	U1
7	1		36-01-031	DIODE, IN 4005, 600 V	D1
6	1		20-05-068	DIP SWITCH, 4 POS	S1
5	1		18-02-445	RES, 4.7 KOHM, 1/4W, 5%	R3
4	1		11-03-143	CAP, 470uf, 25WV	C1
3	1		11-03-134	CAP, 100uf, 25V	C2
2	1		11-03-118A	CAP, 22uf, 16WV	C3
1	1		26-04-440B	PC-440B BOARD	30420

NEXT ASSY	USED ON
	NALL SERIES
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± 1/64; DECIMALS .XX± .01, .XXX± .005; ANGLES ± 2°

MATERIAL: SEE PARTS LIST
FINISH:
DO NOT SCALE DRAWING

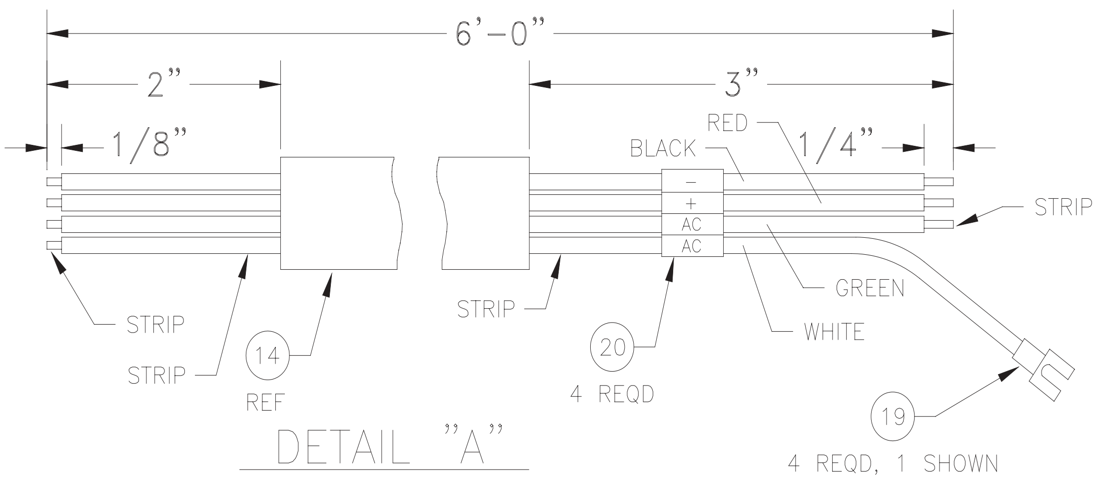
ITEM MASTER NO. 65-118, 65-346, 65-359

APPROVALS		DATE
DRAWN	M WELLS	2/22/95
CHECKED		
ISSUED		

TELEDYNE BROWN ENGINEERING
Hastings instruments

ASSEMBLY DIAGRAM
PC-440B & PC-440BW

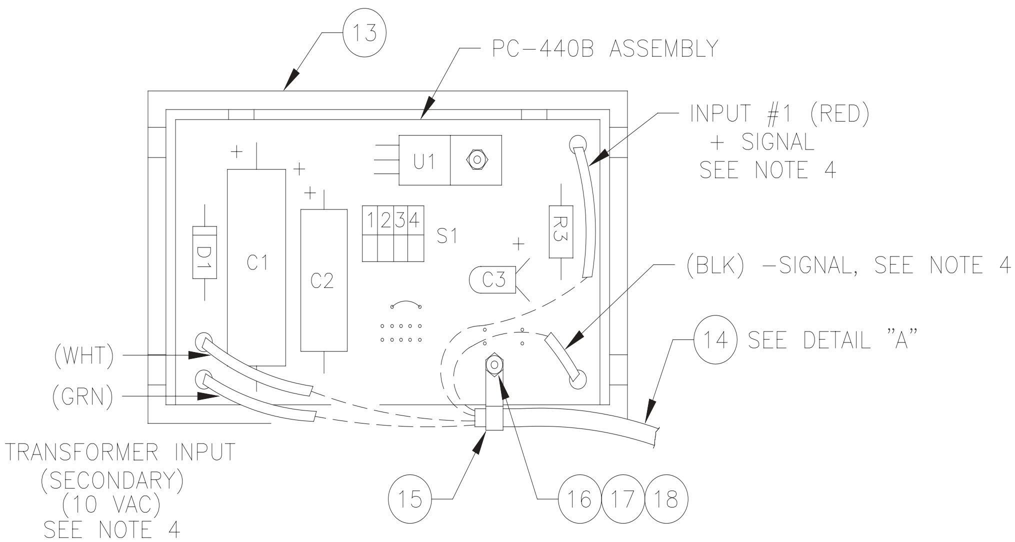
SIZE	FSCM NO.	DWG. NO.	REV
B		30421	D
SCALE NONE		SHEET 1 OF 2	



DETAIL "A"
CABLE ASSEMBLY

ASSEEMBLY NOTES:

1. AFTER ASSEMBLING THE CABLE AS SHOWN IN DETAIL "A" INSTALL THE CABLE TO THE PC-440B ASSEMBLY (65-118) USING THE CABLE CLAMP (ITEM 15) AND 6-32 HARDEWARE AND SOLDERING THE WIRES AS SHOWN.
2. INSTALL THE DIGITAL VOLTMETER (ITEM 13) TO THE PC-440B ASSEMBLY AS SHOWN BY SOLDERING THE APPROPRIATE PINS INTO PLACE.
3. TEST AND INSPECT UNIT AS REQUIRED AND PUT IN STOCK IF ACCEPTED. STORE ASSEMBLY IN STATIC-PROOF BAG.
4. ENLARGE HOLES FOR CABLE WIRES, TO .55 DIA THRU.



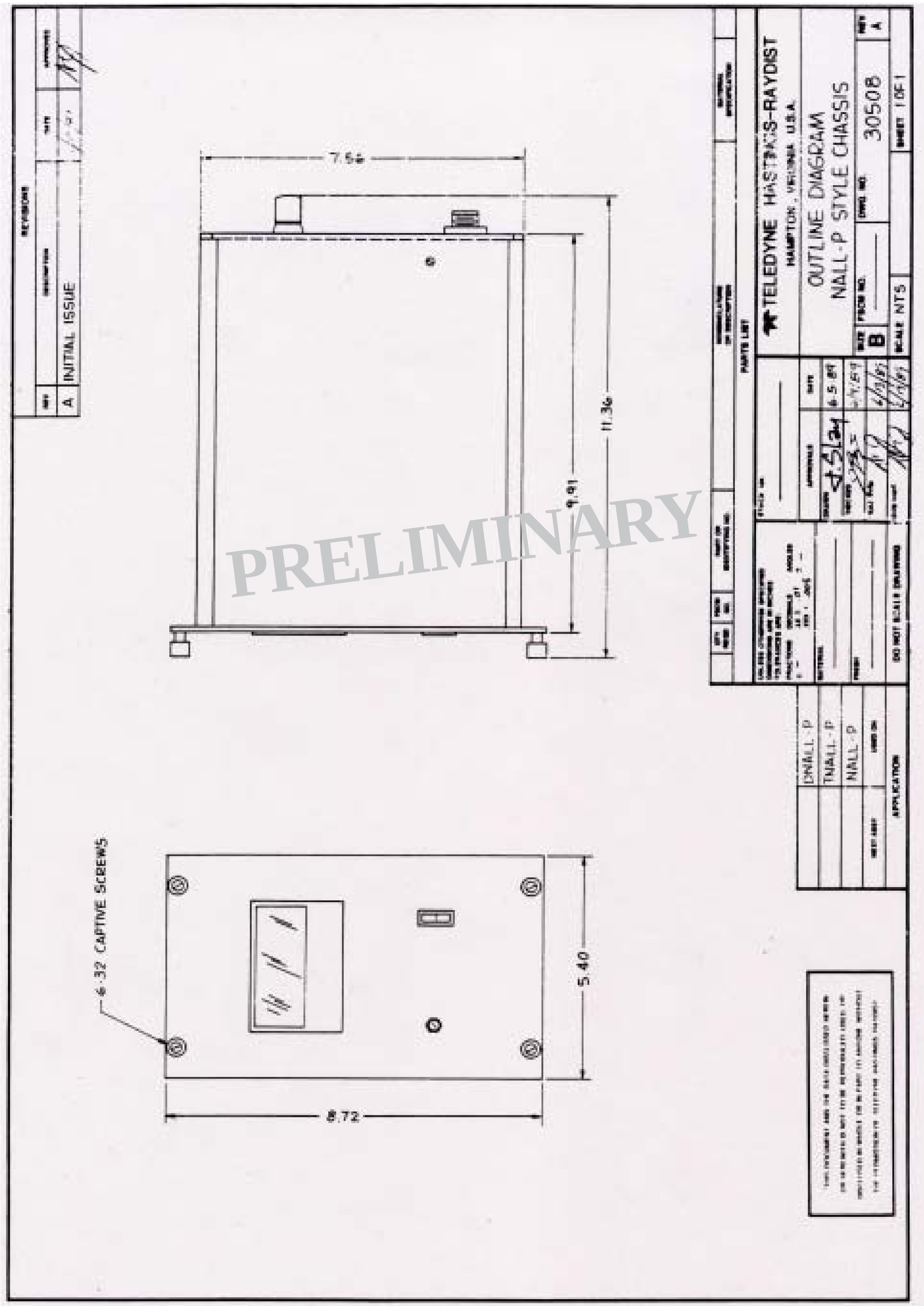
ASSEMBLY VIEW
PC-440BW (65-359)

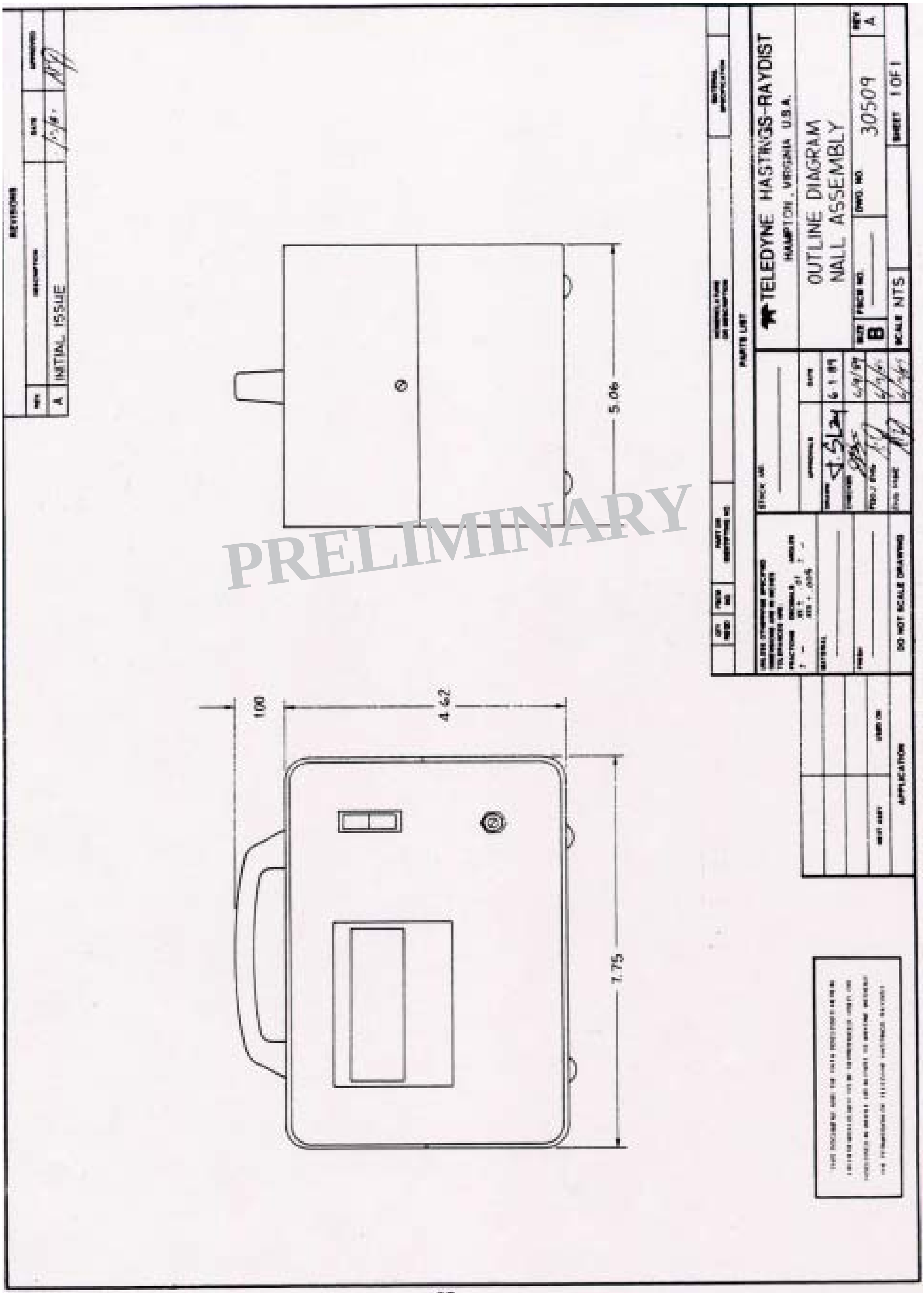
NOTE: THE PARTS LIST SHOWN BELOW CONTAINS THE ADDITIONAL PARTS REQUIRED FOR THE PC-440BW.

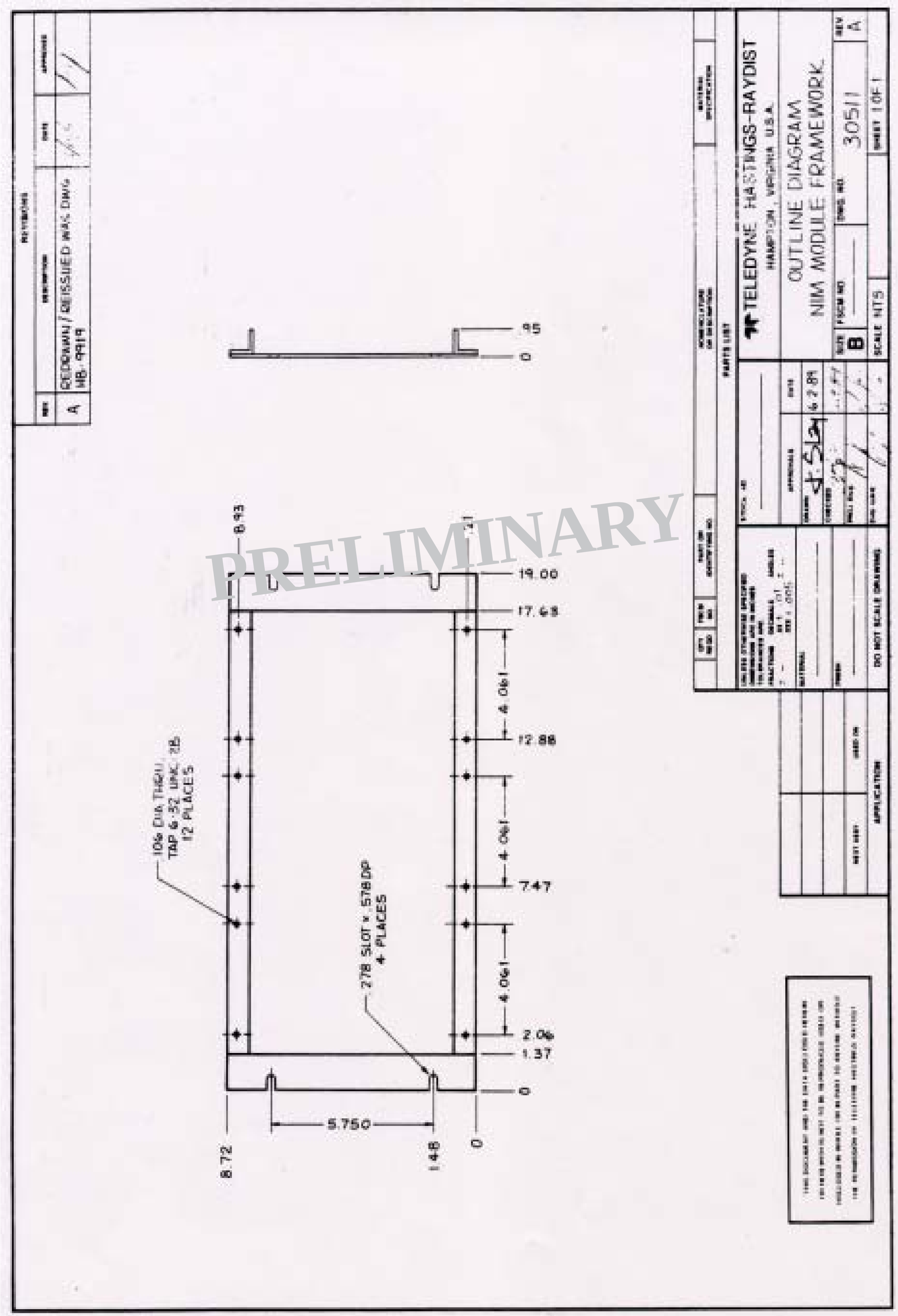
ITEM NO.	QTY REQD	FSCM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION
20	4		–	WIRE LABLES, TUBULAR, PLASTIC
19	4		28-10-105	LUG, SPADE, CRIMP
18	1		–	LOCKWASHER, SPLIT, #6, SS
17	1		–	NUT, 6-32 UNC, SS
16	1		–	SCREW, 6-32 UNC X .38 LG, PH, SS
15	1		–	CABLE CLAMP, PLASTIC
14	1		15-05-014	CABLE, #18 GUAGE / 4 COND
13	1		24-04-006	DIGITAL VOLTMETER

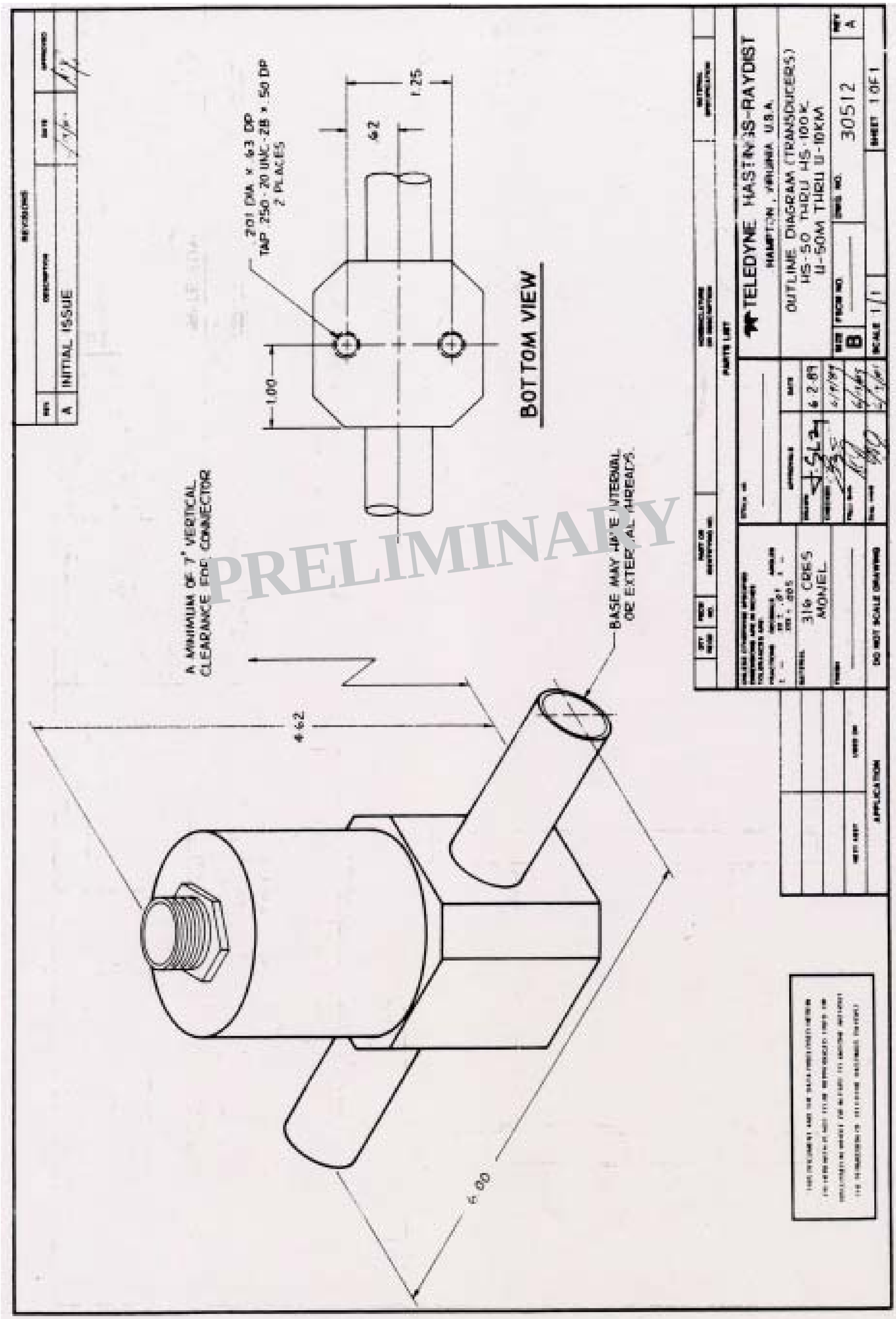
PARTS LIST

TELEDYNE Hastings Instruments	ASSEMBLY DETAILS PC-440BW (65-359)	
DRAWN MARKUS WELLS 2/2/95	SIZE B	FSCM NO.	DWG. NO. 30421	REV D
ISSUED	SCALE NONE	SHEET 2 OF 2

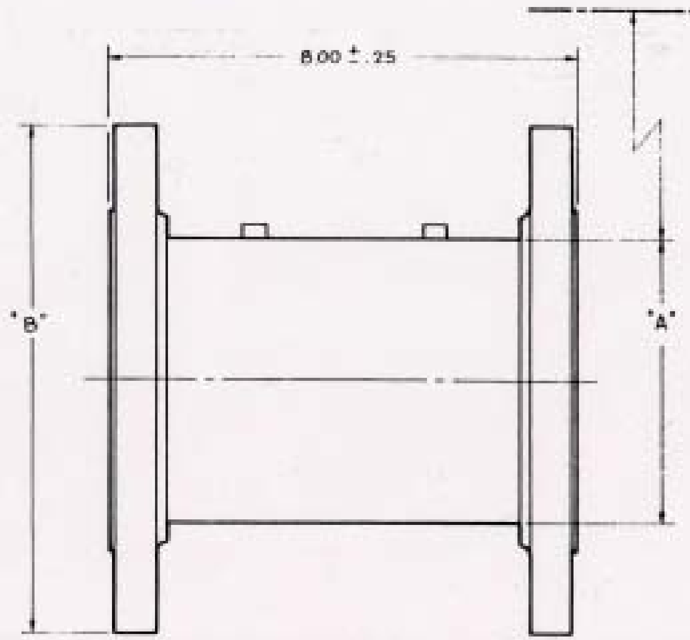

REVISIONS
A INITIAL ISSUE
7.56
11.36
9.91
PRELIMINARY
6-32 CAPTIVE SCREWS
5.40
8.72
PARTS LIST
TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.
OUTLINE DIAGRAM
NALL-P STYLE CHASSIS
B
30508
A
SCALE NTS
SHEET 1 OF 1
DO NOT SCALE DRAWING
DNALL-P
TNALL-P
NALL-P
APPLICATION


REVISIONS
A
INITIAL ISSUE
1.00
4.42
5.06
7.75
PARTS LIST
DO NOT SCALE DRAWING
APPLICATION
TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.
OUTLINE DIAGRAM
NALL ASSEMBLY
B
30509
A
SCALE NTS
SHEET 1 OF 1

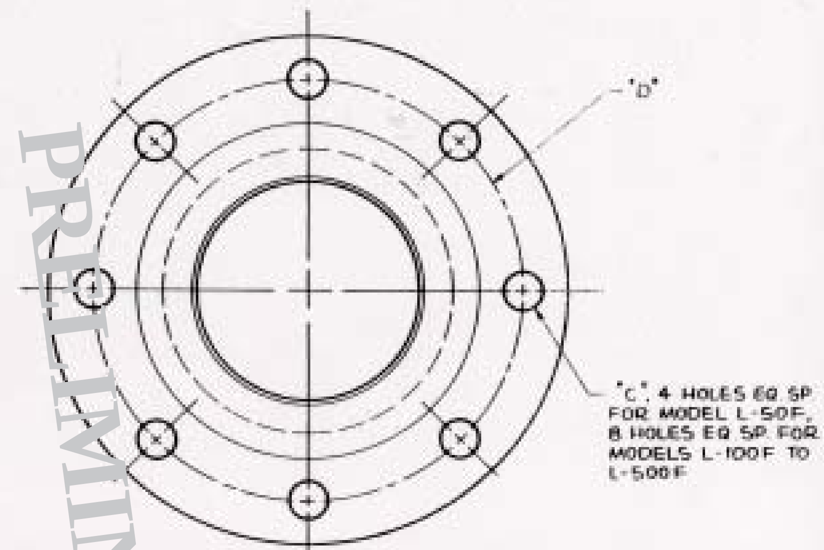

TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.
OUTLINE DIAGRAM
NIM MODULE FRAMEWORK
30511
REV A
SIZE B
SCALE NTS
SHEET 1 OF 1
DO NOT SCALE DRAWING
PARTS LIST
APPLICATION
REVISIONS
A REDRAWN / REISSUED WAS DWG HB-9919
.106 DIA THRU
TAP 6-32 UNC 2B
12 PLACES
.278 SLOT x .578 DP
4 PLACES
19.00
17.69
12.88
7.47
2.06
1.37
0
8.93
.95
0
4.061
4.061
4.061
5.750
8.72
1.48
0



REVISIONS
A INITIAL ISSUE
A MINIMUM OF 7" VERTICAL CLEARANCE FOR CONNECTOR
.201 DIA x .63 DP
TAP .250-20 UNC-2B x .50 DP
2 PLACES
1.00
.62
1.25
BOTTOM VIEW
BASE MAY HAVE INTERNAL OR EXTERNAL THREADS
6.00
316 CRES
MONEL
DO NOT SCALE DRAWING
APPLICATION
TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.
OUTLINE DIAGRAM (TRANSDUCERS)
HS-50 THRU HS-100K
U-50M THRU U-10KM
B
30512
SCALE 1/1
SHEET 1 OF 1



ALLOW 8" MIN. CLEARANCE FOR TRANSDUCER AND CONNECTOR



NOTE: LAMINAR FLOW ELEMENTS L-5, L-10 AND L-25 DO NOT HAVE FLANGES.

PRELIMINARY

TABLE "A"				
MODELS	"A" PIPE SIZE	"B" FLG O.D.	"C" HOLE DIA	"D" B.C. DIA
L-5S & L-5M	1	———	———	———
L-10S & L-10M	1½	———	———	———
L-25S & L-25M	2	———	———	———
L-50SF & L-50MF	3	7.50	.688 4-PL	6.000
L-100SF & L-100MF	4	9.00	.688 8-PL	7.500
L-200SF & L-200MF	6	11.00	.813 8-PL	9.500
L-500SF & L-500MF	8	13.50	.813 8-PL	11.750

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
A	REDRAWN / REISSUED WAS HB-11217		

PARTS LIST

MATERIAL: S = 316 CRES, M = MONEL

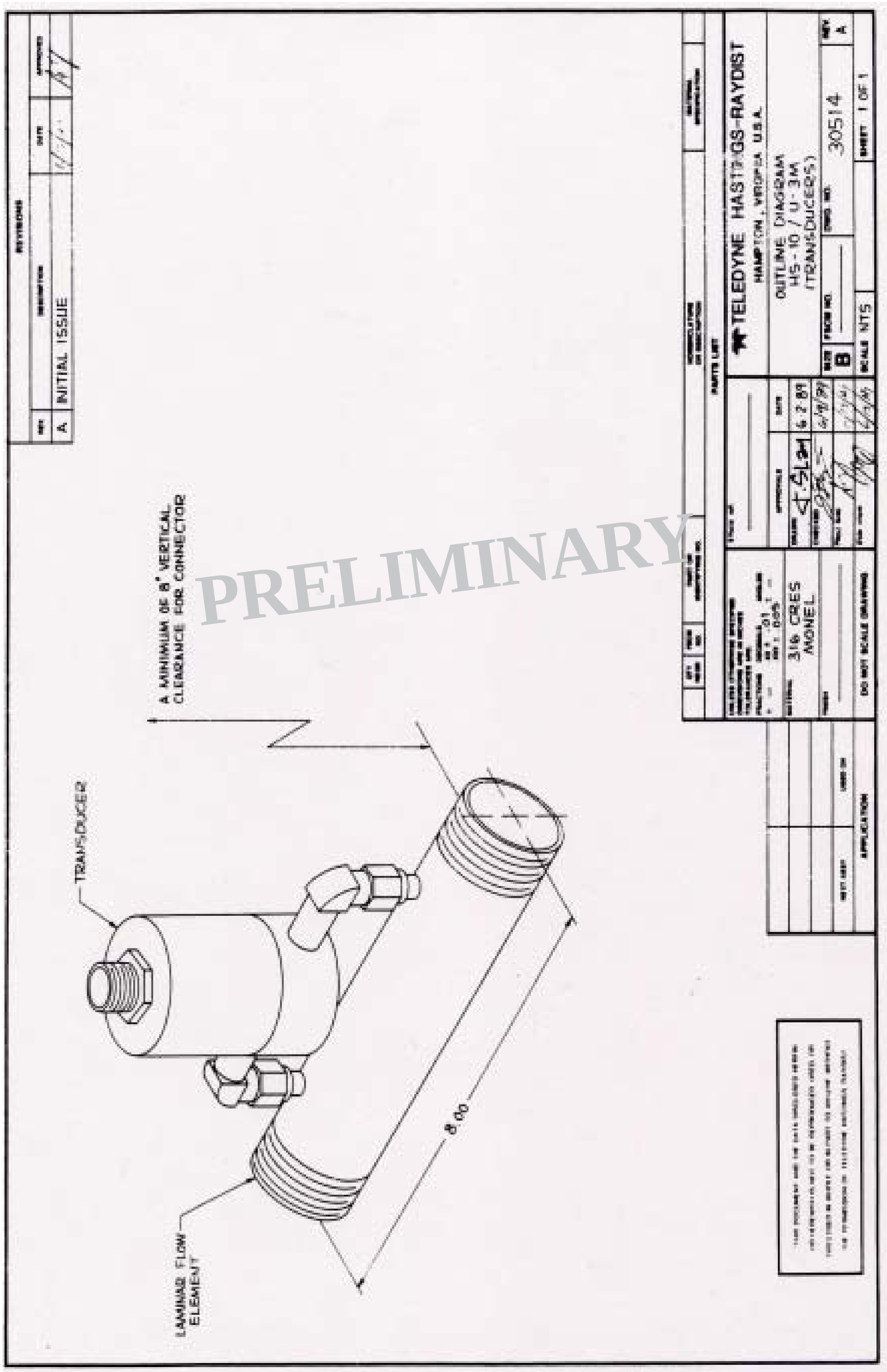
DO NOT SCALE DRAWING

APPLICATION

TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.

OUTLINE DIAGRAM
LAMINAR FLOW ELEMENT
"L" SERIES

SIZE B | DWG NO. 30513 | REV A
SCALE NTS | SHEET 1 OF 1


TRANSDUCER
LAMINAR FLOW ELEMENT
8.00
A MINIMUM OF 8" VERTICAL CLEARANCE FOR CONNECTOR
REVISIONS
A INITIAL ISSUE
PARTS LIST
TELEDYNE HASTINGS-RAYDIST
HAMPTON, VIRGINIA U.S.A.
OUTLINE DIAGRAM
HS-10 / U-3M
(TRANSDUCERS)
B
30514
A
SCALE NTS
SHEET 1 OF 1
316 CRES
MONEL
DO NOT SCALE DRAWING
APPLICATION