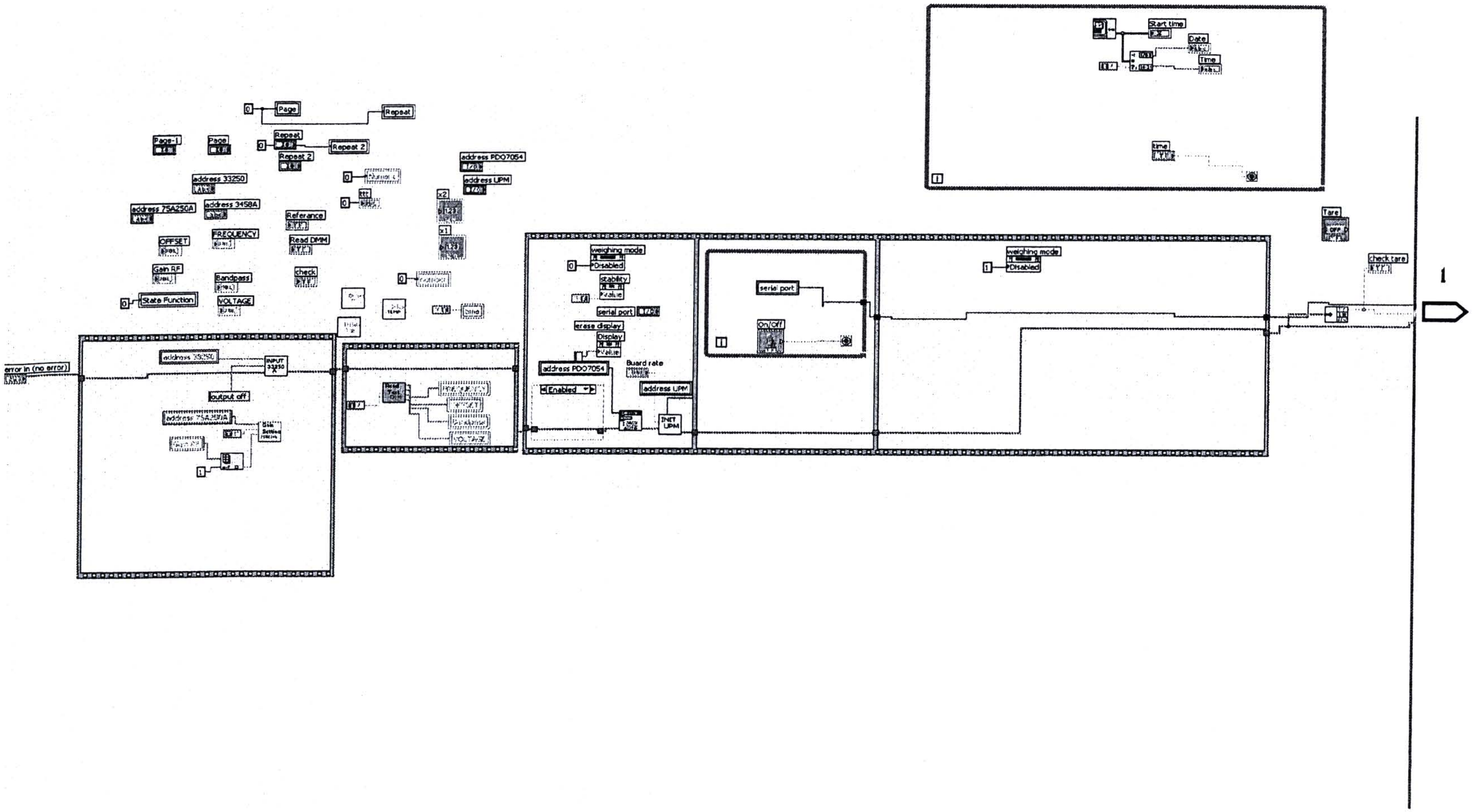
เอกสารอ้างอิง

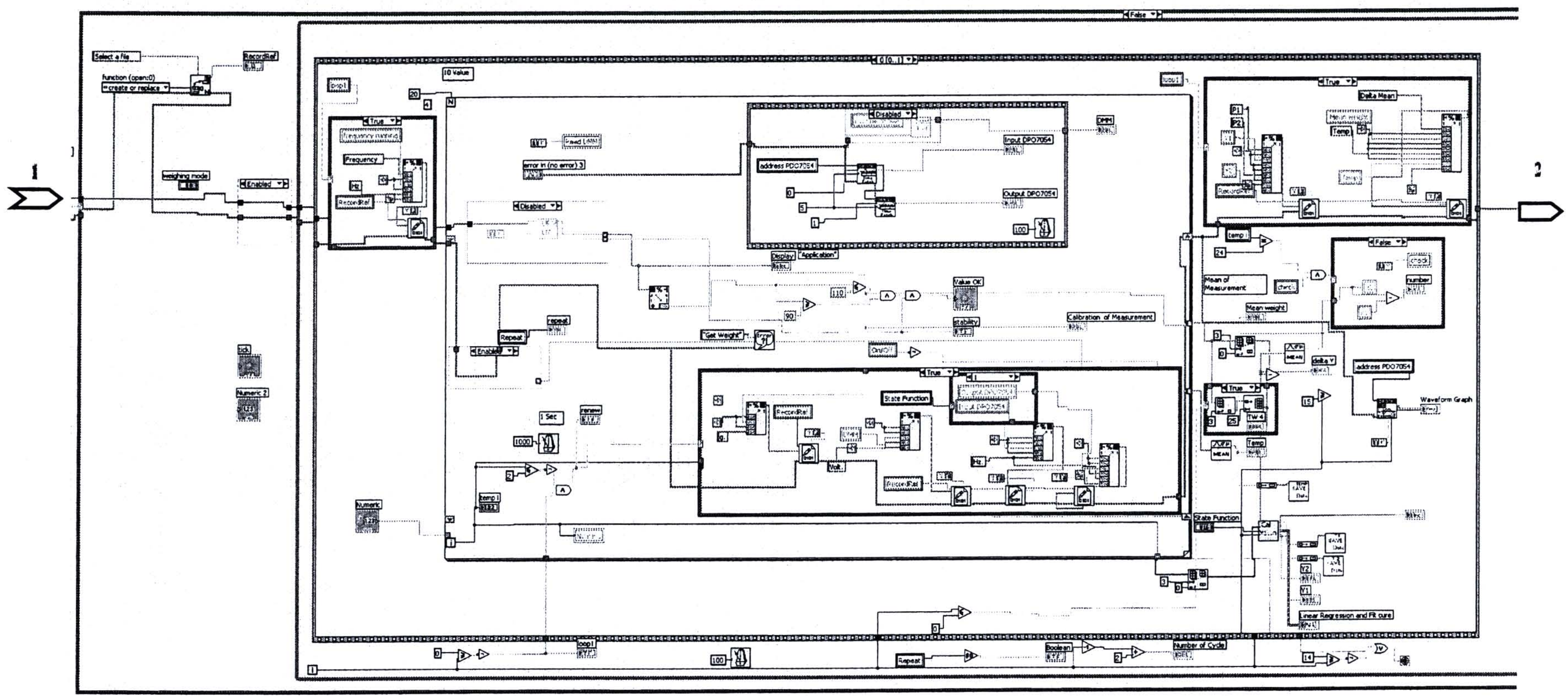
1. ชูศักดิ์ เวชแพทย์. หลักการและเครื่องอุลตร้าซาวด์ทางการแพทย์. กรุงเทพฯ : คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล, 2525.
2. ธีรพร กงบังเกิด. การใช้งานคลื่นอัลตราซาวด์ในกระบวนการแปรรูปอาหาร. [Online] 2547. [สืบค้นวันที่ 18 มกราคม 2554] จาก http://conf.agi.nu.ac.th/agmis/download/publication/79_file.pdf
3. จินตนา ชัชวาลกิจกุล. การวัดกำลังอัลตร้าซาวด์โดยวิธีการวัดแรงการแผ่รังสี. วิทยานิพนธ์วิศวกรรมศาสตรมหาบัณฑิต สาขาวิชามาตรวิทยาทางอุตสาหกรรม คณะวิศวกรรมศาสตร์ บัณฑิตวิทยาลัย มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี, 2546.
4. ชัชวาล พรพัฒน์กุล. เครื่องมือวัดความดันและการสอบเทียบ. พิมพ์ครั้งที่ 1. กรุงเทพฯ : สถาบันเทคโนโลยีปทุมวัน, 2552.
5. Korea Research Institute of Standards and Science . Ultrasonic Power Measurement by Radiation Force Balance Method. Korea : Korea Research Institute of Standards and Science, 2002.
6. Perkins M. "A Versatile Force Balance for Ultrasound Power Measurement." Physics in Medicine & Biology. Vol. 34. No.11. [n.d.] : 1645-1651.
7. International Standard IEC 1161, Ultrasonic Power Measurement in Liquids in the Frequency Range 0.5 MHz to 25 MHz.
8. International Electrotechnical Commission IEC Report Publication 854, Methods of Measuring the Performance of Ultrasonic Pulse-Echo Diagnostic an Equipment.
9. Environmental Health Criteria. ULTRASOUND. Geneva : World Health Organization, 1982.
10. Beissner K. "Primary Measurement of Ultrasonic Power and Dissemination of Ultrasonic Power Reference Values by Means of Standard Transducers." Metrologia. Vol. 36. (1999) : 313-320.

ภาคผนวก ก

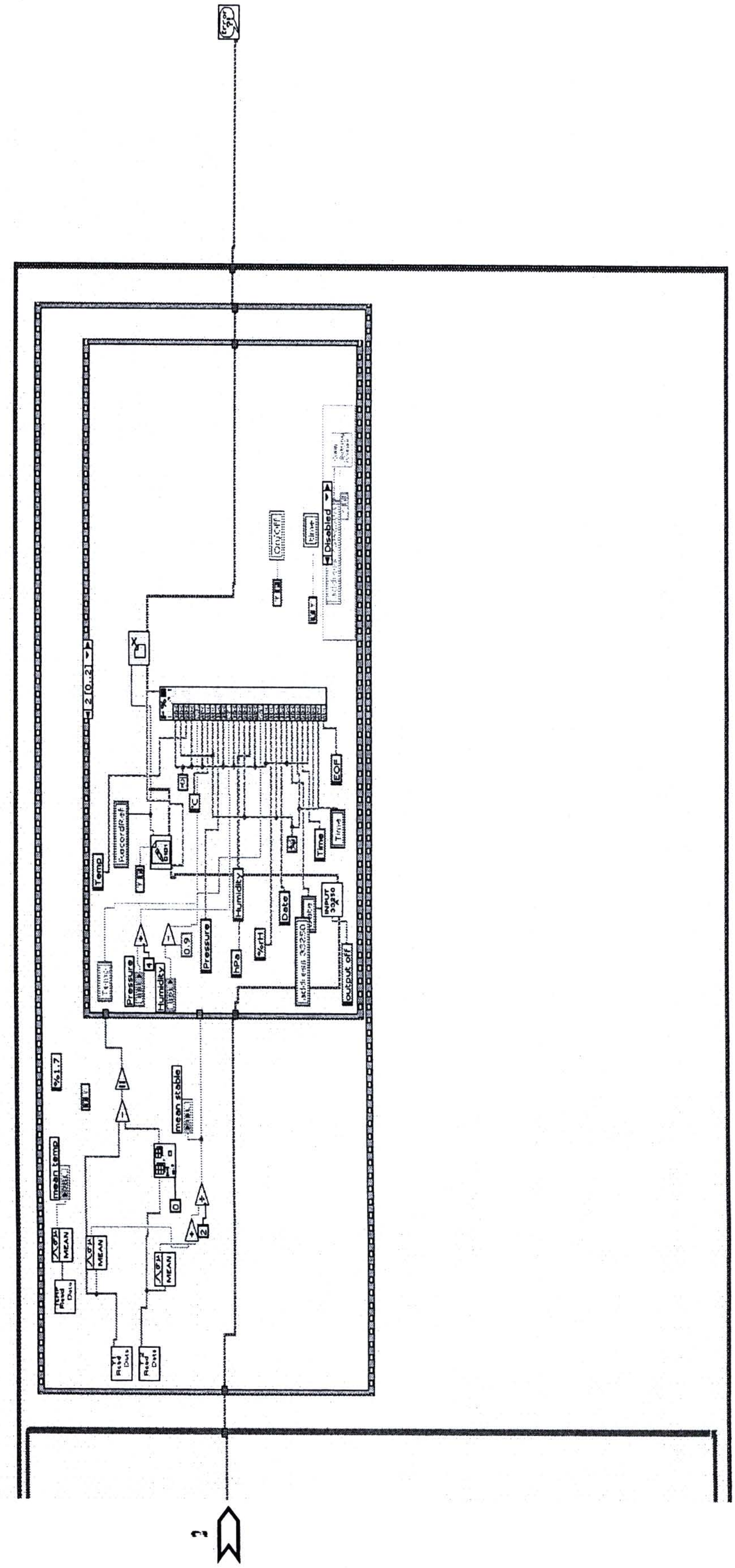
Block Diagram โปรแกรมควบคุมการเปิด –ปิด
เครื่องกำเนิดสัญญาณไฟฟ้า



ภาพที่ ก-1 Block Diagram ควบคุมการเปิด- ปิด เครื่องกำเนิดสัญญาฯไฟฟ้า



ภาพที่ ก-1 (ต่อ)


mean temp
MEAN
mean stable
Temp
Pressure
Humidity
RecordRef
Date
Time
EOF
hPa
%rH
output off
Disabled
0.9

ภาพที่ ก-1 (ต่อ)

ภาคผนวก ข

ใบรับรองผลจากห้องปฏิบัติการ

Certificate of Calibration

dtcert.pub 12/14/04
Rev.:4 ECD

Customer: National Institute of Metrology-Thailand **Date:** Aug. 4, 2005

Sales Order No.: 9069 **Customer Order No.:** 0003558

The following designated equipment was certified on the above date using ASTM E617-97 Class 1 tolerance masses and NIST 105-1 Class F tolerance masses. These masses were certified by Troemner Precision Weights on 14 November 2004. They are next due for certification on 13 November 2005 . This is to certify that the equipment listed below meets Ohmic's accuracy specifications as indicated by the following data and has been referenced against NIST traceable standards, Certs. 303380, 303380A, and 303380B.

EQUIPMENT CALIBRATION REPORT

Model No.: UPM-DT-1 **Description:** Ultrasound Power Meter
Serial No.: 1789

Range: 1 to 30 Watts **Accuracy:** +/- 3% of full scale specification

Calibration Weight	Watts	Before Readings	Before Readings (Watts)	After Readings	After Readings (Watts)
100 mg	1.465 W	— mg	— W	100 mg	1.466 W
200 mg	2.930 W	— mg	— W	200 mg	2.932 W
500 mg	7.325 W	— mg	— W	500 mg	7.325 W
1 G	14.650 W	— G	— W	1.000 G	14.654 W
2 G	29.300 W	— G	— W	2.000 G	29.301 W

Certified By : [signature]
Calibration Technician

ohmic instruments co.
508 August St., Easton, MD 21601
(410)820-5111 (800)626-7713 Fax (410)822-9633
www.ohmicinstruments.com
ohmico

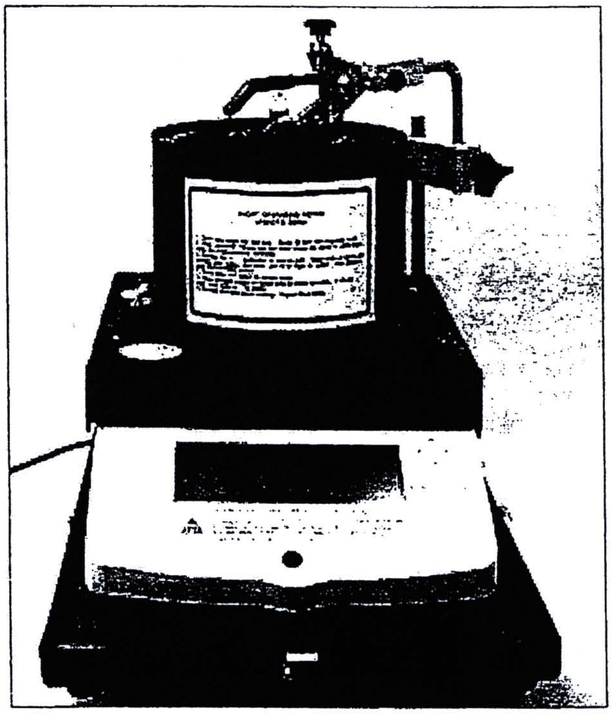
ภาคผนวก ค

คู่มือการใช้งานเครื่องอัลตราซาวด์พาวเวอร์มิเตอร์

ULTRASOUND POWER METER
MODELS UPM-DT-1 & 10

OPERATING MANUAL

July, 1998



ohmic instruments co.
508 August Street, Easton, Maryland 21601
(410)820-5111 (800)626-7713 Fax (410)822-9633
Website: http//www.thomasregister.com/ohmic
E-Mail: ohmic@skipjack.bluecrab.org

ohmico ohmico

WARRANTY

Not withstanding any provision of any agreement the following warranty is exclusive.

OHMIC INSTRUMENTS COMPANY warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of 1-year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, disposable batteries (rechargeable type batteries are warranted for 90-days), or any product or parts which have been subjected to misuse, neglect, accident, or abnormal conditions of operation.

In the event of failure of a product covered by this warranty, Ohmic Instruments Co. will repair and recalibrate an instrument returned within 1 year of the original purchase: provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option, replace the product in lieu of repair. With regard to any instrument returned within 1 year of the original purchase, said repairs or replacement will be made without charge. If the failure has been caused by misuse, neglect, accident, or abnormal conditions of operations, repairs will be billed at a nominal cost. In such case, an estimate will be submitted before work is started, if requested.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS, OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. OHMIC INSTRUMENTS COMPANY SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT, TORT, OR OTHERWISE.

If any failure occurs, the following steps should be taken:

1. Notify Ohmic Instruments Co. giving full details of the difficulty, and include the model, type, and serial numbers (where applicable). Upon receipt of this information service information will be discussed with you. If the problem cannot be rectified then you will be instructed to return the equipment.

2. Returned products are to be shipped to Ohmic Instruments Co. transportation prepaid. Repairs will be made and the instrument returned, transportation prepaid.

SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT

All shipments of Ohmic Instruments Co. instruments should be made via United Parcel Service or "Best Way" prepaid. The instrument should be shipped in the original packing carton, or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER

The instrument should be thoroughly inspected immediately upon delivery to purchaser. All material in the shipping container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact Ohmic Instruments.) Final claim and negotiations with the carrier must be completed by the customer.

OHMIC INSTRUMENTS COMPANY will be pleased to answer all application or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: OHMIC INSTRUMENTS COMPANY, 508 August Street, Easton, Maryland 21601, ATTN.: Technical Support. Or call OHMIC Technical Support at 410-820-5111.

 Information contained within this manual is believed to be accurate and reliable. However, Ohmic Instruments Company assumes no liability for its use. Ohmic Instruments Company reserves the right to supply its instruments with design changes and/or component substitutions that may not be documented in this manual. Contact our engineering department for information on equipment revisions not covered in this manual.

ULTRASOUND POWER METERS, MODELS UPM-DT-1 & 10

Table of Contents

INTRODUCTION

Measurement of power output levels of diagnostic and therapeutic ultrasound equipment has become increasingly important to determine exact patient exposure levels in case a potential risk exists to the patient. Since the Radiation Control for Health & Safety Act of 1968 and the 1976 Medical Device Amendments to the FDA Act became effective, all manufacturers of diagnostic Doppler ultrasound equipment are required to submit information regarding their maximum peak and average exposure level, beam patterns, and other pertinent information. Hospitals are responsible for regularly scheduled testing (every six months) of output power and safety to maintain their accreditation.

The Ultrasound Power Meter, Model UPM-DT Series, is designed to measure the ultrasound power output of diagnostic or therapeutic transducers up to 30 watts. The principle of measurement is the radiant force method. Both models are mechanically identical, each having a positioning clamp to hold the transducer in de-gassed water above a conical target. The ultrasonic energy passes through the water to reflect off the target and then is absorbed by the rubber lining. The radiant power is directly proportional to the total downward force (weight) on the target. This weight is then transferred through the target support assembly to the electro-mechanical load cell inside the scale. The cell is in a computer-controlled feedback loop and produces a digital readout in watts of power (custom units) or grams of force. The choice of units, grams or watts, is selected by front panel pushbuttons. The UPM-DT Series operate on 24 VAC, 50/60 Hz. The units are supplied with plug-in AC adapter for 120 VAC. A mechanical shock mounting in the carrying case protects the electronic balance mechanism. Model UPM-DT-1 has a display resolution of ±2 milliwatts and Model UPM-DT-10 has a display resolution of ±10 milliwatts.

UNPACKING THE UPM-DT POWER METER

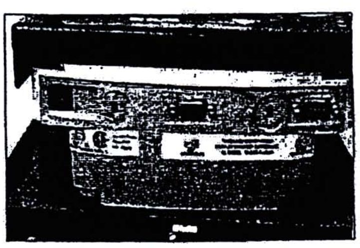
The power meter comes complete with all accessories in a sturdy carrying case. To make ultrasonic measurements, the water tank requires only one pint of de-gassed distilled water. If de-gassed water is not available, use distilled water, NOT tap water.

The parts list for the UPM-DT Series is as follows:

DESCRIPTION OF PART	PART NO
Electronic Balance w/Display UPM-DT-1	E02130
Electronic Balance w/Display UPM-DT-10	E06120
Test Set Base Assembly	DT-TS-BA
Test Tank	DT-TT
Position Clamp Assembly	DT-PCA
Cone Target	DT-CT275
Calibration Weight Standard (14.650 watt)	DT-CW-14
Detachable Line Cord/120VAC Adaptor	DTE-LC6
Instruction Manual	DTE-IN
Carrying Case	DTE-CC

Front view of UPM-DT-1 & 10. Shown is the electronic balance, base assembly, test tank & transducer positioner.

The picture above shows the cone target assembly and transducer positioner. (Tank not shown.)



The rear panel of the UPM-DT Series provides power and RS-232 computer/printer connections. Adjustments to level the unit are made by rotating the rear stands.

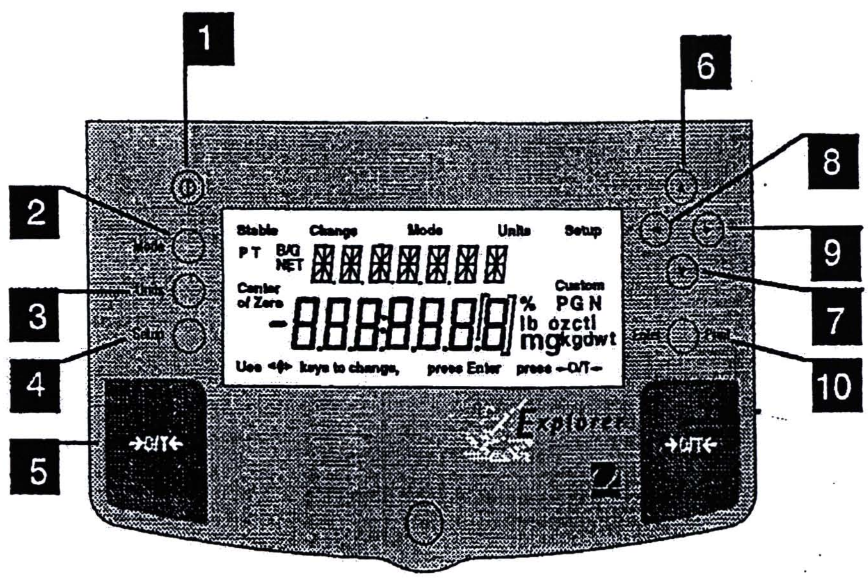
SELECTING A LOCATION FOR OPERATION

The UPM-DT-1 & 10 power meters should always be used in environments free from excessive air currents, corro vibration and temperature or humidity extremes. These factors will affect the displayed readings.

DO NOT operate the power meters:

- Next to open windows or doors causing drafts or rapid temperature changes.
- Near air-conditioning or heat ducts
- Near vibrating, rotating or reciprocating equipment
- Near magnetic fields or equipment that generate magnetic fields
- On an unlevel work surface
- Allow sufficient space around the instrument for ease of operation and keep away from radiant heat sources.
- Never set any material on the power meter or place your hands or fingers on it while taking readings.

PANEL CONTROLS & DISPLAY INDICATOR



1. **Power On/Off** button.
2. **Mode** button; selects standard weighing and animal weighing modes.
3. **Units** button; selects grams-P-C-N-Custom units.
4. **Setup** button (service use only)
5. **→O/T←** button; when pressed, sets UPM-DT to zero.
6. ▲ when pressed, travels up through menus.
7. ▼ when pressed, travels down through menus.
8. ▶ when pressed, travels to the left through menus.
9. ◀ when pressed, travels to the right through menus.
10. **Enter/Print** button; when in menus, selects items on display, otherwise prints data.
11. **Leveling Feet**; used to level the balance (Located at rear)
12. **Leveling Indicator**; indicates leveling position of the balance.
13. **Wing Bracket**; locking unit to case, used for transportation only.

OVERVIEW OF DISPLAY INDICATORS

1. **Use ▶ or ◀ key to change:** used to prompt the user while navigating through the menu system.
2. **Standard (7) segment numeric characters:** seven characters are available and are used for displaying w values.

3. **Center of Zero:** (not used)
4. **P :** (not used)
5. **T :** (not used)
6. **Stable:** indicates that the measured value has become stable.
7. **B/G:** (not used)
8. **Change:** is displayed together with **Mode, Units** or **Setup** signifying that a change to balance settings is being performed.
9. **Mode:** is displayed when the **Mode** button is pressed. Allows the user to know what area of the balance menu is being addressed.
10. **Units:** is displayed when the **Units** button is pressed. Allows the user to know what area of the balance menu is being addressed.
11. **Setup:** is displayed when the **Setup** button is pressed.
12. (British Flag): Are (14) segment alpha numeric characters. Seven characters are used to present features and functions.
13. **Custom:** Displays output watt density (watts/cm^2) based on 10 cm^2 cross sectional area transducer.
14. Symbols for weighing units include:

	DT-1	DT-10
g - grams	x.xxx	x.xx
p - custom watt units	x.xxx	x.xx
c - custom watt units	x.xx	x.x
n - custom watt units	x.x	x.

15. **Press →O/T←:** (not used)
16. Differentiated digit for LFT: (not used)
17. **Press Enter:** Used as a prompt to the user to press the **Enter** button. The menu item displayed is accepted/selected.
18. **Net:** (not used)

OPERATING PROCEDURE

1. Remove the top of the carrying case by unlatching the clamps located on each side. The Ultrasound Power Meter is mounted on the base of the carrying case. **For all applications, the unit must be removed from the carrying case base.**

2. Place the UPM-DT on a stable and level surface (use the Leveling feet and indicator on the unit). Avoid air currents and mechanical vibrations.

3. Loosen the positioning clamp and remove target from the test tank where it is normally stored.

4. Place the back of the tank against the target sleeve. Lower the target rod into the concentric test sleeve located behind the test tank, which simultaneously places the cone target into the tank. If the cone can swing in an arc, it is not down far enough. Tip the rod back slightly to fully engage the rod.

5. Fill the test tank to ¼ inch below the top of the rubber liner with recently de-gassed water at room temperature. *(To obtain de-gassed water, boil distilled water for 20 minutes, fill a jar completely, cover surface with saran wrap, and allow to cool.)*

6. By means of the positioning clamp, attach the transducer head and place its radiating face ¼ inch below the water level, parallel to the water surface, and directly above the center of the cone. Check transducer surface fo uniform wetting (no air pocket or bubbles should be on its surface).

7. Plug the line cord/adapter into a 120 VAC, 50/60 Hz power outlet and depress the ON/OFF button.

8. Allow 5 minutes for the scale to stabilize. With no ultrasonic power applied to the transducer, press either **→O/T·** button to zero the unit.

9. Check low power level response by repeating Step 8 then use the weight of a narrow strip of paper to check the sensitivity of the power meter (10 mg = 0.147 Watts).

10. Apply power to the Transducer Under Test (TUT). Re-zero before each measurement and take your power Determine the maximum peak power with the maximum duty cycle and pulsed output settings with the equation:

$$PAVE = Pp \times Rtpa$$

PAVE = calculated average power
Pp = Peak Pulsed Power Setting on unit under test
Rtpa = Ratio of Temporal Peak to Average Power (from ea. mfr.)

11. After tests are completed, unplug the meter, empty the tank, and place the dry target cone in the tank for protection.

12. Transporting the UPM-DT: Lift off the target cone assembly from the sleeve, empty water into a sealable container, dry the tank and cone, place cone in the tank and clamp the target rod into the storage clips on the side of the target sleeve. Rotate the transducer clamp arm over the top of the tank and stretch the large rubber O-ring from the side clips over the clamp arm and tank. Place unit on base of carrying case and secure it on posts using knobs provided. (For shipping instructions, see Page 7).

OPERATING NOTES

LINE POWER/VOLTAGE: UPM-DT Series meters are set to operate on 12 VAC 50/60 Hz. The unit is supplied with a 120 VAC adapter. Check for correct line voltage before use. For voltages 220/240 VAC, an optional power adapter and line cord are required.

MEASUREMENT RANGE, WATTS & GRAMS: Model UPM-DT-10 has five ranges. When **Custom P** is showing, the UPM-DT-10 displays watts with a resolution of ± 20 milliwatts or ± 0.02 watts. When the grams indicator **g** is on, the resolution is ± milligrams (± 0.01 gram). Each gram equals 14.65 watts and 10 milligrams is equivalent to 146.5 milliwatts (rounded to 0.14 watt). Use **Custom C** mode for most therapy equipment testing. If measurement conditions are not stable, use **Unit N** or **Gram** modes (when using the gram mode multiply the readings by 14.65 to obtain watts).

Model UPM-DT-1 also has five ranges. When watts or milliwatts are being measured, a **Unit** indicator below the display will illuminate. **Unit P** appears for ±2 milliwatt resolution; **Unit C** gives ±10 milliwatts; and **Unit N** displays to the nearest ± 0.1 watt. Use **Unit C** and **N** for all measurements except the lowest range requiring **Unit P** mode. When the gram **g** sign appears, the display gives readings to the nearest ±1 milligram. Each milligram corresponds to 14.65 milliwatts. Depressing the unit button, then ▶ or ◀ buttons will select the desired range.

RE-ZERO/TARE: By depressing the →O/T← button, the meter will zero at the present balance condition. During re-zeroing, the display will be blank until the microprocessor senses a stable condition. If no ultrasound force is applied, then the display will simply indicate true zero reference; otherwise the applied ultrasound will become the offset zero reference. This feature is convenient for automatic zero setting before taking a reading, but also to balance out a fixed ultrasonic power setting and to measure incremental ± deviation from this mean setting.

SET UP: If you accidentally get into **set-up** menu, push right travel button until **exit** is displayed, then push **enter**. The UPM-DT Series Ultrasound Power Meters are custom programmed balances with additional hardware (cone target, tank etc.) designed to provide ultrasound power readings. Entry into the setup menu enables a user to modify certain setup parameters with respect to custom units, calibration stability and linearity. OHMIC Instruments Company assumes no responsibility for the performance of these units if user changes to the internal setup parameters or program is made. Any changes to the internal program parameters voids the warranty and calibration certification. Should reprogramming to the original parameters be required, the unit must be returned to OHMIC's facility in Easton, Maryland. An hourly labor rate of $75 will be charged plus recalibration fees will be accessed.

CALIBRATION

A 1-gram calibration weight is supplied. With the transducer under test turned off, zero the unit by pressing the **→O/T←** button. Place the weight on the arm of the cone target. Within 60 seconds the units should read 14.65 watts (± 1%). A set of precision weights and a scale pan assembly is needed to recalibrate the unit. Send the unit to our service department for calibration. A calibration kit (DTE-CAL Kit) is also available. If you accidentally get into **CAL** mode, push the right travel button until **EXIT** is displayed, then push **enter**. It is recommended that these units be returned to OHMIC Instruments Co on a yearly basis for recalibration and recertification.

PROGRAMMING PRINT CONTROL

The Print menu provides a number of options which can be turned on or off. It contains eight submenus: **Auto Print**, which includes selection of Off, Continuous, Interval and Stability; **Inter**, which specifies time interval for automatic output of displayed data; **Stable**, a data-only feature; **Numeric** only or full display data for output; **PrtDate, PrtTime, Reference**, which prints reference weight value, and; **Lock**, which enables you to program balance parameters and to lock the settings.

Procedure:

- Press the **Setup** button; CAL is displayed.
- Press ▸ or ◂ button until PRINT is diplayed.
- Press **Enter** button to save setting
- Press ▸ or ◂ button until either AUTOPRT, INTER, STABLE, NUMERIC, PRTDATE, PRTTIME, REFEREN, LOCK or EXIT displayed.
- Press **Enter** button to save setting.
- Press ▴ or ▾ button and select either menu setting or On or Off.
- Press **Enter** button to save setting.
- Press ▸ or ◂ button to continue to LOCK or EXIT.
- Press **Enter** button to save setting.

AUTO PRINT FEATURE: When enabled, the Auto Print feature causes the balance to automatically output display data in one of three ways: continuously, at user specified time intervals, or upon stability. Default settings are shown **bold:**

- **OFF** - when set on, turns off the auto print feature
- **Cont** - when set on, outputs printed data continuously
- **Inter** - provides a user specified printing interval
- **On Stb** - provides printed data only when a stable reading is achieved

INTERVAL: Can be set to provide a specified printing interval between 1 and 3600 seconds.

PRINT STABLE DATA ONLY: When set On, this feature permits only stable display data to be output. **OFF** is the default setting.

PRINT NUMERIC DATA ONLY: When Numeric Data Only function is turned ON, this allows the balance to output numeric data only for RS232 output. **OFF** is the default setting.

PRINT TIME: When the Time function is set ON, allows the balance to output the current time to the printer. **OFF** is the default setting. See Setting, Date and Time on Page .

PRINT DATE: When the Date function is set ON, allows the balance to output the current date to the printer. **OFF** is the default setting.

REFERENCE: When the Reference function is ON, prints the value of weight used as a reference in either Percent or Parts Counting modes. **OFF** is the default setting.

LOCK: **Lock ON/OFF can only be changed when the hardware Lock Switch is set OFF/disabled.** A menu is locked when the menu lock is set ON and the Lock switch is ON. Lock when selected and turned on locks all of the entries made under the Print menu. In the locked condition, items may be looked at but not changed in the menu. When set off, entries may be changed. **OFF** is the default setting.

SETTING DATE AND TIME

The UPM-DT Series provides date and time data which can be viewed on a computer or printed out on an external printer When you put your new instrument into operation for the first time, you should enter the current date and the time. These settings are retained as long as the balance remains connected to a power source.

Date is a feature which enables the balance to be set to a U.S. date standard or European. U.S. standard has the month day and year each separated by a / in the printout. The European date standard has the day, month and year each separated by a period. The default setting is U.S.A. standard.

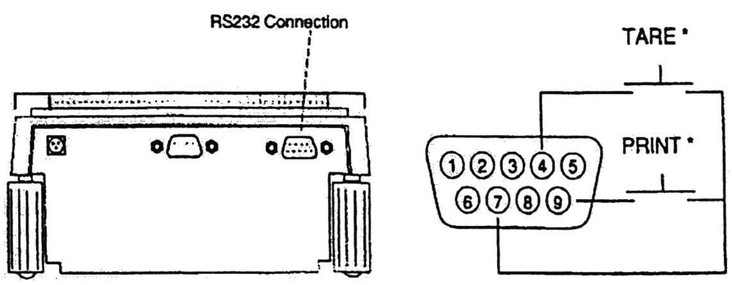
PROCEDURE:
- Press the **Setup** button, CAL is displayed.
- Press ▶ or ◀ button and select Date from the menu.
- Press **Enter** button, TYPE is displayed.
- Press **Enter** button, SET M d y, d M y, y M d, M y d, y d M, or d y M is displayed.
- Press ▲ or ▼ button and select type of date.
- Press **Enter** button, SAVED is displayed, then SET is displayed.
- Press **Enter** button, first digit of date is flashing.
- Using ▲ or ▼ buttons, enter the correct date.
- When the correct date is entered, press **Enter** button.
- SAVED displays momentarily and EXIT appears.
- Press **Enter** button, balance returns to weighing mode.

Time is a feature which enables the balance to be set to the current time in either U.S. standards (12 hour periods) or European/military standards (24 hour periods). The default setting is U.S.A. standard.

PROCEDURE:
- Press the **Setup** button, CAL is displayed.
- Press ▶ or ◀ button and select Time from the menu.
- Press **Enter** button, TYPE is displayed.
- Press **Enter** button, TYPE 12 hr is displayed.
- Press ▲ or ▼ button and select 12 hr or 24 hr.
- Press **Enter** button, SAVED is displayed momentarily then SET is displayed.
- Press **Enter** button, SET with time is flashing.
- Using arrow buttons, enter the correct time.
- When the correct time is entered, press **Enter** button.
- SAVED displays momentarily and EXIT appears.
- Press **Enter** button, balance returns to weighing mode.

Adjustments up to ± 60 seconds a month can be made to the balance's internal clock. Repeat the first seven steps, ADJUST is displayed. Using arrow buttons, enter time correction and press **Enter** button.

SERIAL COMPUTER/PRINTER INTERFACE



1 N/C
2 Data Out (TXD)
3 Data In (RXD)
4* Tare (External Signal)
5 Clear to Send (CTS)
6 Data Terminal Ready (DTR)
7 Ground
8 Request to Send (RTS)
9* Print (External Signal)

** External PRINT and/or TARE switches may be installed as shown above. Momentary contact switches must be used.*

RS-232 INTERFACE: The UPM-DT-1 and UPM-DT-10 power meters are equipped with a bi-directional RS-232 compatible interface for communication with printers and computers. When the balance is connected direct to a printer, displayed data can be output at any time by simply pressing **PRINT** or by using the Auto Print feature. Connecting the balance to a computer enables you to operate the balance from the computer, as well as receive data such as displayed weight, weighing mode, stability status, etc.

HARDWARE: On the rear of the balance, the right hand 9-pin male subminiature "D" connector is provided for interfacing to other devices. The balance will not output any data unless pin 5 (CTS) is held in an ON state (+3 to +15V DC).

Interfaces not utilizing the CTS handshake may tie pin 5 to pin 6 to defeat it.
OUTPUT FORMATS: Data output can be initiated in one of three ways: 1) by pressing PRINT; 2) using the Auto Print feature or; 3) sending a print command ("P") from a computer.

DEFAULT SETTINGS: Baud-2400, Data Bits-7, Parity-none, Stop Bits-2, Lock-off.

RS-232 COMMANDS: All communication is accomplished by standard ASCII format. Characters shown in the following table are acknowledged by the balance. Invalid command response "ES" error indicates the balance has not recognized the command. Commands sent to the power meter must be terminated with a carriage return-line feed (CRFL).

Command Character	Description
?	Prints current mode: Mode, Stability, CR, LF
nnnA	Set Auto Print Feature: nnn = 0 Turns feature OFF nnn = S Output on Stability nnn = C Output is continuous nnnn = 1-3600 Sets Auto Print interval in seconds
P	Print Display Data
xD	Set 1 second print delay: x = 0 for OFF x = 1 for ON
T	Tare (Same effect as pressing O/T button)
ON	Turns Balance on.
OFF	Turns balance off.
TIME	Prints current time.
mm/dd/yy SETDATE	Set date
hh:mm:ss SETTIME	Set Time

The UPM-DT Series Ultrasound Power Meters are custom programmed balances with additional hardware (cone target tank etc.) designed to provide ultrasound power readings. When utilizing the RS-232 interface certain setup command may be entered that enable changes to the internal programming with respect to custom units, calibration stability an linearity. ONLY THE COMMANDS ABOVE SHOULD BE USED. OHMIC Instruments Company assumes no responsibil ity for the performance of these units if user changes to the internal program are made. Any changes to the interna program parameters voids the warranty and calibration certification. Should reprogramming to the original parameters b required, the unit must be returned to OHMIC's facility in Easton, Maryland. An hourly labor rate of $75 will be charge plus recalibration fees will be accessed.

SHIPPING INSTRUCTIONS FOR UPM-DT SERIES POWER METERS

To make certain that your Ultrasound Power Meter arrives at our repair department unharmed during shipment, pleas follow these instructions:

1. Empty water from tank and lock scale.

2. Wrap the target cone in a protective covering and place in tank; **do not put target support bracket in the tabletop tube nor in the clips** (if tank should move during shipment, the bracket will be damaged).

3. Place the weight under the screw provided. Make sure the transducer clamp assembly is screwed in place tight over the tank and pull the rubber O-ring over the tank and clamp (if O-ring not available, use heavy duty rubber bands).

4. Secure unit in case using wing brackets and knobs.

5. Fasten the case lid onto the base, after making certain that there is nothing loose inside.

6. The package used for shipping should be strong and large enough to allow for adequate packing material on all

sides of unit.

7. Ship to:
OHMIC Instruments Company
508 August Street
Easton, Maryland USA 21601

8. Enclose paperwork (packing slip, purchase order form, letterhead) which includes your return address, contact name and telephone number. A description of the work which needs to be done would be helpful.

By using the above instructions, you will avoid additional charges which can be incurred if the unit is not packaged well enough to withstand rough handling during shipment.

SPECIFICATIONS

	UPM-DT-1	UPM-DT-10
Power Range	0 to 30 Watts	0-30 Watts
Resolution	±2mW	±10mW
Minimum Detectable Power	1mW	10mW
Display Sensitivity	0.001/0.01/0.1 Watt	0.01/0.1/1 Watt
Accuracy	±3% + One Digit	±3% + One Digit
Zeroing Method	Automatic	Automatic
Averaging of Measured Values	100	100
Stabilization	2.5 Second Integration	2.5 Second Integration
Maximum Weight Capacity	210 Grams	600 Grams
Maximum Transducer Size	3" Diameter	3" Diameter
Transducer Operating Frequency	1-10MHz	1-10MHz
Test Media	Degassed Water	Degassed Water
Computer Interface	RS-232, 300-9600 Baud	RS-232, 300-9600 Baud
Default Baud Rate	2400	2400
Power	12VAC, 1 Amp	12VAC, 1 Amp
120 VAC Adaptor Supplied (Adaptors for 240VAC Available on Special Order)	120VAC to 12VAC w/3-Prong Male Plug and 6Ft Cord	120VAC to 12VAC w/3-Prong Male Plug and 6Ft Cord
EMI Rating	Conforms to CE & FCC	Conforms to CE & FCC
Electrical Safety	Conforms to UL & CSA	Conforms to UL & CSA
Size	11"H x 15" Lx 10"W	11"H x 15" Lx 10"W
Weight	22 Lbs Net	22 Lbs Net
Carrying Case	Black Anodized Aluminum	Black Anodized Aluminum

MAINTENANCE

VERIFICATION OF PROPER SCALE FUNCTIONING: Small variations of water surface motion, air currents or mechanical movements may cause uncertainties in power measurements. To test scale accuracy at low levels, set up the scale as in the Operating Procedures (page 3). Place the 14.65 watt weight on the flat surface of the target arm. Read meter three times; readings should be within ± 1% (for example, 14.504 to 14.796 to UPM-DT-1 and 14.52 to 14.80 for UPM-DT-10). In case of doubt about lower power level resolution, repeat the same procedure using light objects such as thin paper slices to produce readings of 5 to 10 counts; repeat readings. Average uncertainty should be within ± 2 counts on the grams as well as on the watts scale. Avoid mechanical and air movement or variations in magnetic fields while making tests.

OUT OF MEASUREMENT RANGE WARNINGS: Model UPM-DT-1 accommodates weight differential of ± 200 grams while UPM-DT-10 accommodates ± 600 grams. When the scale exceeds this range, "Error 8.3" will be displayed. Something may be pressing hard on the target or support. "Error 8.4" indicates underweight condition. This will occur if the target is out of place on the UPM-DT-1.

NO DISPLAY: 1) Check power and line cord; 2) verify that the line voltage is set correctly.

If you need further assistance, please call our service department.

WATER, TANK SIZE,TRANSDUCER PLACEMENT & TEMPERATURE CONSIDERATIONS

WATER AS A MEASUREMENT MEDIUM: The measurements are to be performed in de-gassed water because ultrasound propagation in water closely approximates that in tissues (see UL-1-1981, AIUM/NEMA Standard Publication). The ultrasonic attenuation in water can be taken as a lower limit on the attenuation which will be encountered in the body. Large areas in the body can consist of low attenuating material such as urine and amniotic fluid. The use of water prevents measurements in a more highly attenuating material such as liver equivalent gels from representing the highest possible intensities which might be encountered in the body. A measurement temperature of 24°C ± 3°C (75°F ± 5) is chosen for convenience.

DE-GASSED WATER: Ultrasound power measurement accuracy is affected (by lowering the power reading) if the water contains more than five parts per million of air. To de-gas, boil distilled water for one half hour, then pour into a suitable container, seal tightly and place in refrigerator. This process will give the required quality. The container should be heat resistant glass; or thick plastic may be used after the water has been cooled. Before testing, pour water into tilted test tank to minimize turbulence. The test tank water surface will absorb oxygen and a change of de-gassed water is recommended before each test. An alternative method of de-gassing water is to heat the water to the boiling point, then put a vacuum to it for five to ten minutes.

Water temperature affects accuracy; use a testing temperature of 21 to 24°C ambient. Sonic energy agitates the water surface through heating and scattering. Testing time should be limited to a few minutes; prolonged testing, particularly at higher power levels, will drive out dissolved air and air bubbles will be visible on surfaces in the tank. These bubbles can be gently brushed off.

TRANSDUCER WETTING & PLACEMENT: After tilting the transducer into the water at a 45° angle, verify that the surface is uniformly wetted; if not, wipe the surface clean. The transducer should be positioned above the cone target. Small variations will occur due to placement. Try various positions above target to obtain a maximum power reading.

ULTRASOUND RADIATION LEVELS

There are no maximum limits in the U.S. for therapy power, only the verification of the displayed setting accuracy t accuracy ± 20% of actual output is required. Exposure levels for physical therapy applicator heads range fror 100mW/cm^2 to 3W/cm^2. Total power requires multiplication by the radiated cross sectional area in cm^2.

The power limits shown in the following table for diagnostic ultrasound have been extracted from FDA Section 510(l guidance to manufacturers on submissions and clearance as of February 1993. Refer to the AIUM and FDA publicatior for complete and up to date testing standards and interpretations. Measurements are done in all standard modes (operation. Power intensity is rated as Spatial Peak Temporal Average (I_{SPTA}) and Spatial Peak Pulse Average (I_{SPPA}). Th values in mW/cm^2 are derated for tissue and in parenthesis for the water medium (use this column):

PRE-AMENDMENT ACOUSTIC OUTPUT LIMITS

Use	I_{SPTA} (mW/cm^2) Tissue Water		I_{SPPA} (W/cm^2) Tissue Water	
Peripheral Vessel	720	(1500)	190	(350)
Fetal Imaging & Other*	430	(730)	190	(350)
Cardiac	94	(180)	190	(350)
Ophthalmic	17	(68)	28	(110)

* Abdominal, intra-operative, pediatric, small organ (breast, thyroid, testes, etc.), neonatal cephalic, adult cephalic

THEORY OF MEASURING ULTRASOUND POWER WITH THE RADIATION FORCE METHOD

Sound is a form of energy that sets the particles in the isonated medium into vibrational motion. The particles then possess a kinetic energy. If **dP_m** is the rate of the flow of this energy about an area **dA**, then the mean acoustic energy is:

Eq. 1 $\quad I = dP_m/dA \quad$ I = Acoustic intensity at a point in that area, Watts/cm^2

When a plane sound wave propagates through a uniform non-absorbent medium, the intensity must be the same for all point sin the wave. Let **E** represent the energy density, i.e., the energy per unit volume. When the sound energy passes through a unit cross -sectional area with a speed **c**, the intensity is:

Eq. 2 $\quad I = cE \quad$ E = Energy density per unit volume, ergs/cm^3
c = Ultrasound wave velocity, cm/sec

The radiation pressure effect can be explained by analogy to the application of an alternating electric voltage to a non linear load. With the non-linear load it appears that both AC and DC components are present. In ultrasonics the non-linear element is the density of the fluid and hence acoustic impedance (load) varies in the same periodical manner a the density. Therefore in ultrasound the two components of pressure, one alternating and the other direct are present. The average AC pressure per cycle is zero, but the DC pressure of radiation is:

Eq. 3 $\quad P_\tau = I/C \quad$ P_τ = Pressure of Radiation, ergs/cm^3

Therefore, from the above two equations, the pressure of radiation (P_τ) is equal to the energy density (E) .

Eq. 4 $\quad P_\tau = E$

It is this DC pressure of radiation that can be measured. At low frequencies, below 100 KHz, a standard high frequency hydrophone can be used. For higher frequencies, generally used in medical applications, 1-15 MHz, hydrophones are not available. At these frequencies the force can be measured using a precision balance and a radiation force target that is perfectly absorptive. The conversion from force to power can be accomplished using the equation:

Eq. 5 $\quad p = Wgc \quad$ W = measured force, grams
g = acceleration, dynes
c = velocity of ultrasound, cm/sec
p = power, ergs/sec

By combining all constants together and converting from ergs/sec to watts, we obtain a simplified equation that is used to calculate the ultrasonic power once the force is measured.

Eq. 6 $\quad P = w(14.65) \quad$ P = Ultrasonic power in watts
w = Ultrasonic force in grams

To determine the ultrasonic watt density (watts/cm^2 or watts/in^2) of a given transducer the P is divided by the cross sectional area of the transducer.

ULTRASONIC THERAPY UNIT INSPECTION RECORD	ACTION: NOT NEEDED	ACTION: NEEDED	ACTION: TAKEN	WORK ORDER NO.

LOCATION	MANUFACTURER	DATE OF INSPECTION	CARD COLUMNS	WORK ORDER TRANSACTION
UNIT MODEL	TRANSDUCER MODEL	NEXT INSPECTION DUE	1-15	STOCK NO.
UNIT SERIAL NO.	TRANSDUCER SERIAL NO.	TECHNICIAN	18	DETACHMENT
1. PREVENTIVE MAINTENANCE INSPECTION	SAT.	UNSAT.	20-24	INDEX NO.
REMARKS			26-29	PM MANHOURS
			30	PM MINUTES
2. FUNCTIONAL/OPERATIONAL CHECKOUT	SAT.	UNSAT.	32-35	REPAIR HOURS
REMARKS			36	REPAIR MINUTES
3. LEAKAGE CURRENT - CHASSIS - 100uA TRANSDUCER - 50uA	SAT.	UNSAT.	38-43	CONTRACT COSTS

TEST CONDITION	POWER	CHASSIS	TRANSDUCER		
				45	REPAIRMAN'S CODE
GROUNDED NORMAL POLARITY	ON			47-50	DATE COMPLETED
	OFF			51-52	ACTION CODE
GROUND LIFTED NORMAL POLARITY	ON			53-60	WORK ORDER NO.
	OFF			61-66	RC/CC
GROUND LIFTED REVERSE POLARITY	ON			67-69	DOWN DAYS
	OFF			70-75	QUANTITY INSPECTED

4. GROUND WIRE RESISTANCE (150 milliohms Max.)	_____ m ohms	78-80	TRANSACTION CODE

5. TIMER	TOL.	SELECTED	TIMED	[redacted]	
< 8 MIN.	± 0.8 MIN.			6. ANNUAL INSPECTION REQUIREMENTS COMPLETED	DATE
8 M. - 10 MIN.	± 10%			7. IS UNIT SUBJECT TO 21CFR1050 REQUIREMENTS?	YES/NO
> 10 MIN.	± 1.0 MIN.			8. COMBINED MUSCLE STIMULATOR INSPECTED?	YES/NO

REMARKS

WORK PERFORMED BY	LABEL AFFIXED:
	USER MAINTENANCE:

. CONTINUOUS WAVE MODE CERTIFICATION (Average Power)

/ATTS ELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE		WATTS SELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE	
	1					3.7 - 6.3		10	1					7.4 - 12.6	
	2								2						
	3					SAT.	UNSAT.		3					SAT.	UNSAT.
	Average Of 3 Readings								Average Of 3 Readings						
/ATTS ELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE		WATTS SELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE	
	1					11.1 - 18.9		20	1					14.8 - 25.2	
5	2								2						
	3					SAT.	UNSAT.		3					SAT.	UNSAT.
	Average Of 3 Readings								Average Of 3 Readings						
/ATTS ELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE		WATTS SELECT		POWER ON	POWER OFF	DIFF.	WATTS OUT	ALLOWABLE RANGE	
	1								1						
	2								2						
	3					SAT.	UNSAT.		3					SAT.	UNSAT.
	Average Of 3 Readings								Average Of 3 Readings						

EMARKS:

0. PULSED MODE CERTIFICATION (Amplitude Modulated Waveform)

MAX. PULSE MODE SETTING	POWER ON	POWER OFF	DIFF.	WATTS OUT	CALCULATIONS:
(P_p)	Average Of 3 Readings				= Measured Average Power (Av)

P_p	R_{TPA}	CALC. AVERAGE POWER (P_p / R_{TPA})	Difference Between Measured AV And Calculated AV	Is Difference < ±0.6%) Of (P_p / R_{TPA}) YES/NO	REMARKS:

1. SHORT TERM LIFE TEST COMPLETE? YES / NO

:2. ADDITIONAL TEST (Describe In Detail):

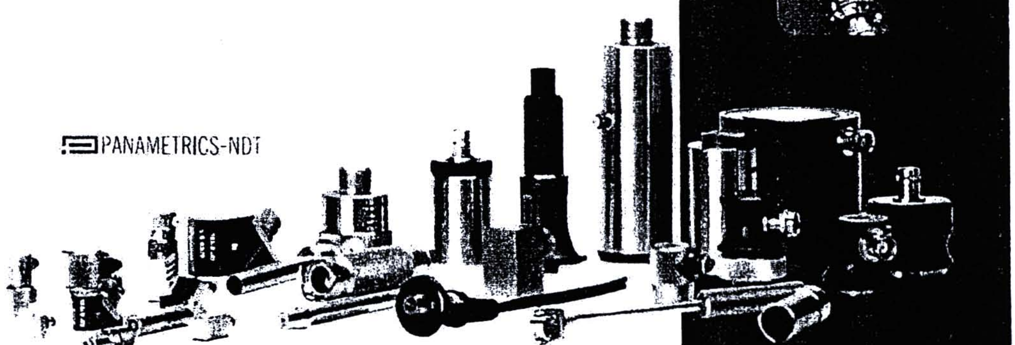
ภาคผนวก ง

คุณลักษณะของหัวทรานสดิวเซอร์

Ultrasonic Transducers Technical Notes

OLYMPUS

PANAMETRICS-NDT



Technical Notes

The Technical Notes section is designed to provide a brief overview of the ultrasonic principles important to transducer application and design. The Technical Notes are organized in the following sections:

1. Basic Ultrasonic Principles
2. Advanced definitions and formulas
3. Design characteristics of transducers
4. Transducer specific principles
5. Transducer excitation guidelines
6. Cables

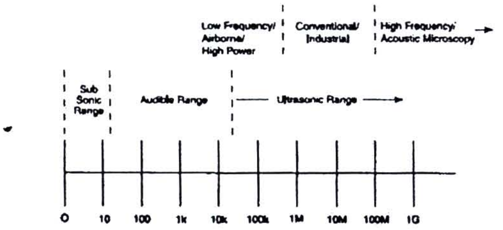
1. BASIC ULTRASONIC PRINCIPLES

a. What is Ultrasound?

Sound generated above the human hearing range (typically 20 kHz) is called ultrasound. However, the frequency range normally employed in ultrasonic nondestructive testing and thickness gaging is 100 kHz to 50 MHz. Although ultrasound behaves in a similar manner to audible sound, it has a much shorter wavelength. This means it can be reflected off very small surfaces such as defects inside materials. It is this property that makes ultrasound useful for nondestructive testing of materials.

The Acoustic Spectrum in Figure (1) breaks down sound into 3 ranges of frequencies. The Ultrasonic Range is then broken down further into 3 sub sections.

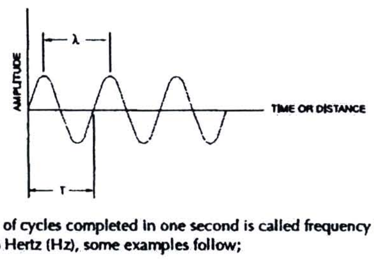
Fig. 1



b. Frequency, Period and Wavelength

Ultrasonic vibrations travel in the form of a wave, similar to the way light travels. However, unlike light waves, which can travel in a vacuum (empty space), ultrasound requires an elastic medium such as a liquid or a solid. Shown in Figure (2) are the basic parameters of a continuous wave (cw). These parameters include the wavelength (λ) and the period (T) of a complete cycle.

Fig. 2



The number of cycles completed in one second is called frequency (f) and is measured in Hertz (Hz), some examples follow;

- 1 cycle/second= 1Hz
- 1000 cycles/second= 1kHz
- 1,000,000 cycles/second= 1MHz

The time required to complete a full cycle is the period (T), measured in seconds. The relation between frequency and period in a continuous wave is given in Equation (1).

Eqn. 1 $$f = 1/T$$

c. Velocity of Ultrasound and Wavelength

The velocity of ultrasound (c) in a perfectly elastic material at a given temperature and pressure is constant. The relation between c, f, λ and T is given by Equations (2) and (3):

Eqn. 2 $$\lambda = c/f$$ Eqn. 3 $$\lambda = cT$$

λ = Wavelength
c = Material Sound Velocity
f = Frequency
T = Period of time

Table 1 on page 48 lists the longitudinal and shear wave velocities of materials that are commonly tested with ultrasonics.

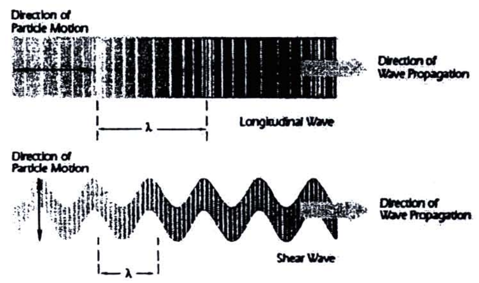
d. Wave Propagation and Particle Motion

The most common methods of ultrasonic examination utilize either longitudinal waves or shear waves. Other forms of sound propagation exist, including surface waves and Lamb waves.

- The longitudinal wave is a compressional wave in which the particle motion is in the same direction as the propagation of the wave.
- The shear wave is a wave motion in which the particle motion is perpendicular to the direction of the propagation.
- Surface (Rayleigh) waves have an elliptical particle motion and travel across the surface of a material. Their velocity is approximately 90% of the shear wave velocity of the material and their depth of penetration is approximately equal to one wavelength.
- Plate (Lamb) waves have a complex vibration occurring in materials where thickness is less than the wavelength of ultrasound introduced into it.

Figure (3) provides an illustration of the particle motion versus the direction of wave propagation for longitudinal waves and shear waves.

Fig. 3



e. Applying Ultrasound

Ultrasonic nondestructive testing introduces high frequency sound waves into a test object to obtain information about the object without altering or damaging it in any way. Two basic quantities are measured in ultrasonic testing; they are time of flight or the amount of time for the sound to travel through the sample, and amplitude of received signal. Based on velocity and round trip time of flight through the material the material, thickness can be calculated as follows:

Eqn. 4 $$T = \frac{ct}{2}$$

T = Material Thickness
c = Material Sound Velocity
t = Time of Flight

Technical Notes

Measurements of the relative change in signal amplitude can be used in sizing flaws or measuring the attenuation of a material. The relative change in signal amplitude is commonly measured in decibels. Decibel values are the logarithmic value of the ratio of two signal amplitudes. This can be calculated using the following equation. Some useful relationships are also displayed in the table below;

Eqn. 5 $$dB = 20\log_{10}(A_1/A_2)$$

- dB = Decibels
- A_1 = Amplitude of signal 1
- A_2 = Amplitude of signal 2

A_1/A_2	Ratio	dB
100% / 70.71%	1.4142	3
100% / 50%	2	6
100% / 25%	4	12
100% / 10%	10	20
100% / 1%	100	40

f. Sensitivity and Resolution

- Sensitivity is the ability of an ultrasonic system to detect reflectors (or defects) at a given depth in a test material. The greater the signal that is received from these reflectors, the more sensitive the transducer system.
- Axial resolution is the ability of an ultrasonic system to produce simultaneous and distinct indications from reflectors located at nearly the same position with respect to the sound beam.
- Near surface resolution is the ability of the ultrasonic system to detect reflectors located close to the surface of the test piece.

2. ADVANCED DEFINITIONS AND FORMULAS

a. Transducer Waveform and Spectrum

Transducer waveform and spectrum analysis is done according to test conditions and definitions of ASTM E1065. Typical units are MHz for frequency analysis, microseconds for waveform analysis, and dB down from peak amplitude. Figure (4) illustrates waveform duration at the -14 dB level or 20% amplitude of peak. The -40 dB waveform duration corresponds to 1% amplitude of peak.

Fig. 4

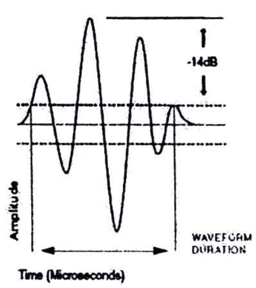
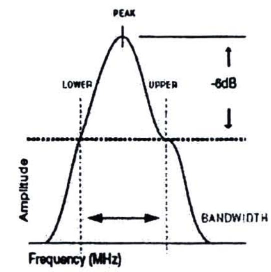


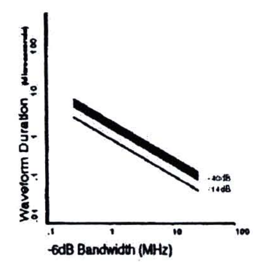
Figure (5) illustrates peak frequency, upper and lower -6 dB frequencies and MHz bandwidth measurements.

Fig. 5



The relation between MHz bandwidth and waveform duration is shown in Figure (6). The scatter is wider at -40 dB because the 1% trailing end of the waveform contains very little energy and so has very little effect on the analysis of bandwidth. Because of the scatter it is most appropriate to specify waveforms in the time domain (microseconds) and spectra in the frequency domain.

Fig. 6



The approximate relations shown in Figure (6) can be used to assist in transducer selection. For example, if a -14 dB waveform duration of one microsecond is needed, what frequency transducer should be selected? From the graph, a bandwidth of approximately 1 to 1.2 MHz corresponds to approximately 1 microsecond -14 dB waveform duration. Assuming a nominal 50% fractional bandwidth transducer, this calculates to a nominal center frequency of 2 to 2.4 MHz. Therefore, a transducer of 2.25 MHz or 3.5 MHz may be applicable.

b. Acoustic Impedance, Reflectivity and Attenuation

The acoustic impedance of a material is the opposition to displacement of its particles by sound and occurs in many equations. Acoustic impedance is calculated as follows:

Eqn. 6 $$Z = \rho c$$

- Z = Acoustic Impedance
- c = Material Sound Velocity
- ρ = Material Density

The boundary between two materials of different acoustic impedances is called an acoustic interface. When sound strikes an acoustic interface at normal incidence, some amount of sound energy is reflected and some amount is transmitted across the boundary. The dB loss of energy on transmitting a signal from medium 1 into medium 2 is given by:

Eqn. 7a $$dB\ loss = 10\ Log_{10}\ [4Z_1Z_2 / (Z_1 + Z_2)^2]$$

- Z_1 = Acoustic Impedance of First Material
- Z_2 = Acoustic Impedance of Second Material

Technical Notes

The dB loss of energy of the echo signal in medium 1 reflecting from an interface boundary with medium 2 is given by:

Eqn. 7b $$\text{dB loss} = 10 \text{ Log}_{10} [(Z_2 - Z_1)^2 / (Z_1 + Z_2)^2]$$

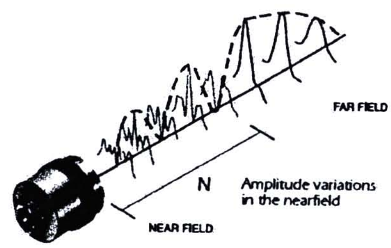
For example: The dB loss on transmitting from water (Z = 1.48) into 1020 steel (Z = 45.41) is -9.13 dB; this also is the loss transmitting from 1020 steel into water. The dB loss of the backwall echo in 1020 steel in water is -0.57 dB; this also is the dB loss of the echo off 1020 steel in water. The waveform of the echo is inverted when $Z_2 < Z_1$.

Finally, ultrasound attenuates as it progresses through a medium. Assuming no major reflections, there are three causes of attenuation: diffraction, scattering and absorption. The amount of attenuation through a material can play an important role in the selection of a transducer for an application.

c. Sound Field

The sound field of a transducer is divided into two zones; the near field and the far field. The near field is the region directly in front of the transducer where the echo amplitude goes through a series of maxima and minima and ends at the last maximum, at distance N from the transducer.

Fig. 7



The location of the last maximum is known as the near field distance (N or Y_0^+) and is the natural focus of the transducer. The far field is the area beyond N where the sound field pressure gradually drops to zero. Because of the variations within the near field it can be difficult to accurately evaluate flaws using amplitude based techniques. The near field distance is a function of the transducer frequency, element diameter, and the sound velocity of the test material as shown by Equation 8:

Eqn. 8 $$N = D^2 f / 4c$$ Eqn. 8a $$N = D^2 / 4\lambda$$

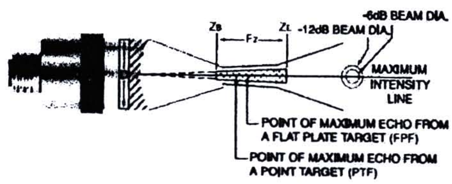
N = Near Field Distance
D = Element Diameter
f = Frequency
c = Material Sound Velocity
λ = Wavelength

(Table 2 on page 48 lists the near field distances in water for many combinations of transducer frequency and element diameter.)

d. Other Parameters of a Sound Beam

There are a number of sound field parameters that are useful in describing the characteristics of a transducer. In addition to the near field, knowledge of the beam width and focal zone may be necessary in order to determine whether a particular transducer is appropriate for a given inspection. Figure (8) gives a graphical representation of these parameters:

Fig. 8



Z_B = Beginning of the Focal Zone
F_Z = Focal Zone
Z_E = End of the Focal Zone
D = Element Diameter

Note that the distance to the maximum echo from a flat plate target and the maximum echo from the point target are not the same, although both will occur within the calculated -6 dB focal zone.

Beam Diameter

A transducer's sensitivity is affected by the beam diameter at the point of interest. The smaller the beam diameter, the greater the amount of energy is reflected by a flaw. The -6 dB pulse-echo beam diameter at the focus can be calculated with Equation 9 or 9a. For a flat transducer use Equation 9a with $S_F = 1$

Eqn. 9 $$BD(-6\text{ dB}) = 1.02Fc/fD$$

Eqn. 9a $$BD(-6\text{ dB}) = .2568DS_F$$

BD = Beam Diameter
F = Focal Length
c = Material Sound Velocity
f = Frequency
D = Element Diameter
S_F = Normalized Focal Length (Eqn. 14)

Focal Zone

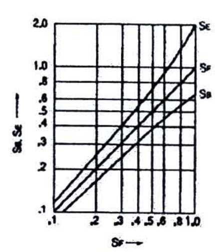
The starting and ending points of the focal zone are located where the on-axis pulse-echo signal amplitude drops to - 6 dB of the amplitude at the focal point. The length of the focal zone is given by Equation 10:

Eqn. 10 $$F_Z = N \cdot S_F^2 [2/(1 + .5S_F)]$$

F_Z = Focal Zone
N = Near Field
S_F = Normalized Focal Length (Eqn. 14)

Figure (9) shows the normalized beginning (S_B) and ending (S_E) point of the -6 dB focal zone versus the focusing factor.

Fig. 9
-6 dB Focal Zone

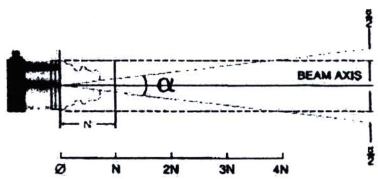


Normalized Beginning & Ending Points of the -6dB Focal Zone as Measured by Signal Amplitude From Small Ball

Technical Notes

Beam Spread and Half Angle
All ultrasonic beams diverge. In other words, all transducers have beam spread. Figure (10) gives a simplified view of a sound beam for a flat transducer. In the near field, the beam has a complex shape that narrows. In the far field the beam diverges.

Fig. 10



For flat transducers as shown in Figure (10), the - 6 dB pulse-echo beam spread angle is given by Equation (11):

Eqn. 11 $$\sin(\alpha/2) = .514c/fD$$

$\alpha/2$ = Half Angle Spread between -6 dB points

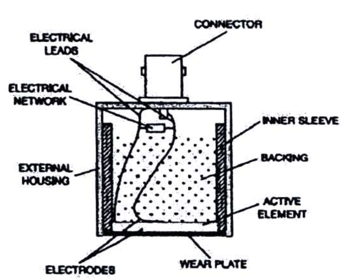
It can be seen from this equation that beam spread from a transducer can be reduced by selecting a transducer with a higher frequency or a larger element diameter or both.

3. DESIGN CHARACTERISTICS OF TRANSDUCERS

a. What is an Ultrasonic Transducer?

A transducer is any device that converts one form of energy to another. An ultrasonic transducer converts electrical energy to mechanical energy, in the form of sound, and vice versa. The main components are the active element, backing, and wear plate.

Fig. 11



b. The Active Element

The active element, which is piezo or ferroelectric material, converts electrical energy such as an excitation pulse from a flaw detector into ultrasonic energy. The most commonly used materials are polarized ceramics which can be cut in a variety of manners to produce different wave modes. New materials such as piezo polymers and composites are also being employed for applications where they provide benefit to transducer and system performance.

c. Backing

The backing is usually a highly attenuative, high density material that is used to control the vibration of the transducer by absorbing the energy radiating from the back face of the active element. When the acoustic impedance of the backing matches the acoustic impedance of the active element, the result will be a heavily damped transducer that displays good range resolution but may be lower in signal amplitude. If there is a mismatch in acoustic impedance between the element and the backing, more sound energy will be reflected forward into the test material. The end result is a transducer that is lower in resolution due to a longer waveform duration, but may be higher in signal amplitude or greater in sensitivity.

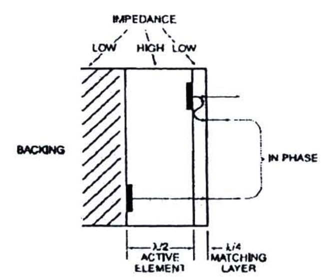
d. Wear Plate

The basic purpose of the transducer wear plate is to protect the transducer element from the testing environment. In the case of contact transducers, the wear plate must be a durable and corrosion resistant material in order to withstand the wear caused by use on materials such as steel.

For immersion, angle beam, and delay line transducers the wear plate has the additional purpose of serving as an acoustic transformer between the high acoustic impedance of the active element and the water, the wedge or the delay line all of which are of lower acoustic impedance. This is accomplished by selecting a matching layer that is 1/4 wavelength thick ($\lambda/4$) and of the desired acoustic impedance (the active element is nominally 1/2 wavelength). The choice of the wear surface thickness is based upon the idea of superposition that allows waves generated by the active element to be in phase with the wave reverberating in the matching layer as shown in Figure (4).

When signals are in phase, their amplitudes are additive, thus a greater amplitude wave enters the test piece. Figure (12) shows the active element and the wear plate, and when they are in phase. If a transducer is not tightly controlled or designed with care and the proper materials, and the sound waves are not in phase, it causes a disruption in the wavefront.

Fig. 12



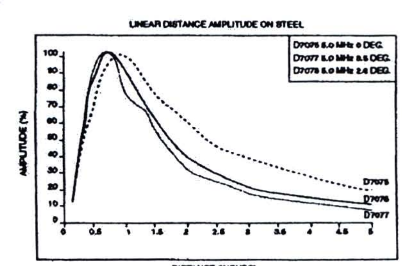
4. TRANSDUCER SPECIFIC PRINCIPLES

a. Dual Element Transducers

Dual element transducers utilize separate transmitting and receiving elements, mounted on delay lines that are usually cut at an angle (see diagram on page 8). This configuration improves near surface resolution by eliminating main bang recovery problems. In addition, the crossed beam design provides a pseudo focus that makes duals more sensitive to echoes from irregular reflectors such as corrosion and pitting.

One consequence of the dual element design is a sharply defined distance/amplitude curve. In general, a decrease in the roof angle or an increase in the transducer element size will result in a longer pseudo-focal distance and an increase in useful range, as shown in Figure (13).

Fig. 13

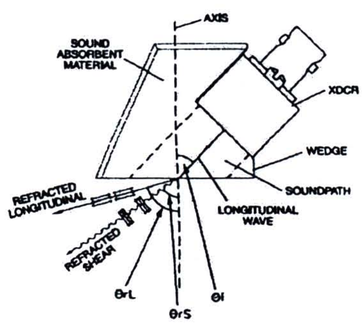


Technical Notes

b. Angle Beam Transducers

Angle beam transducers use the principles of refraction and mode conversion to produce refracted shear or longitudinal waves in the test material as shown in Figure (14).

Fig. 14



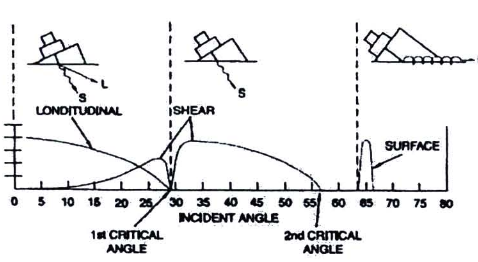
The incident angle necessary to produce a desired refracted wave (i.e. a 45° shear wave in steel) can be calculated from Snell's Law as shown in Equation (12). Because of the effects of beam spread, this equation doesn't hold at low frequency and small active element size. Contact us for details concerning these phenomena.

Eqn. 12 $$\sin\theta_i / c_i = \sin\theta_{rl} / c_{rl} = \sin\theta_{rs} / c_{rs}$$

θ_i = Incident Angle of the Wedge
θ_{rl} = Angle of the Refracted Longitudinal Wave
θ_{rs} = Angle of the Refracted Shear Wave
c_i = Velocity of the Incident Material (Longitudinal)
c_{rl} = Material Sound Velocity (Longitudinal)
c_{rs} = Velocity of the Test Material (Shear)

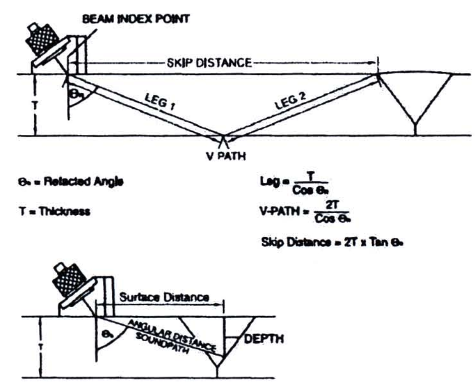
Figure (15) shows the relationship between the incident angle and the relative amplitudes of the refracted or mode converted longitudinal, shear, and surface waves that can be produced from a plastic wedge into steel.

Fig. 15



Angle beam transducers are typically used to locate and/or size flaws which are oriented non-parallel to the test surface. Following are some of the common terms and formulas used to determine the location of a flaw.

Fig. 16



Surface Distance = Sin θr x Soundpath
Depth (1st Leg) Cos θr x Soundpath
Depth (2nd Leg) = 2T - [Cos θr x Soundpath]

Many AWS inspections are performed using refracted shear waves. However, grainy materials such as austenitic stainless steel may require refracted longitudinal waves or other angle beam techniques for successful inspections.

c. Delay Line Transducers

Delay line transducers are single element longitudinal wave transducers used in conjunction with a replaceable delay line.
One of the reasons for choosing a delay line transducer is that near surface resolution can be improved. The delay allows the element to stop vibrating before a return signal from the reflector can be received. When using a delay line transducer, there will be multiple echoes from end of the delay line and it is important to take these into account.

Another use of delay line transducers is in applications in which the test material is at an elevated temperature. The high temperature delay line options listed in this catalog (page 16, 17, 19) are not intended for continuous contact, they are meant for intermittent contact only.

d. Immersion Transducers

Immersion transducers offer three major advantages over contact transducers:

- Uniform coupling reduces sensitivity variations.
- Reduction in scan time due to automated scanning.
- Focusing of immersion transducers increases sensitivity to small reflectors.

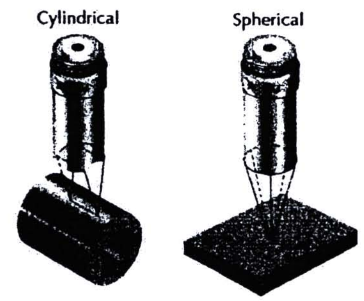
Focusing Configurations

Immersion transducers are available in three different configurations: unfocused ("flat"), spherically ("spot") focused, and cylindrically ("line") focused. Focusing is accomplished by either the addition of a lens or by curving the element itself. The addition of a lens is the most common way to focus a transducer.

An unfocused transducer may be used in general applications or for penetration of thick materials. A spherically focused transducer is commonly used to improve sensitivity to small flaws and a cylindrical focus is typically used in the inspection of tubing or bar stock. Examples of spherical and cylindrical focusing are shown in Figure (17).

Technical Notes

Fig. 17



By definition, the focal length of a transducer is the distance from the face of the transducer to the point in the sound field where the signal with the maximum amplitude is located. In an unfocused transducer, this occurs at a distance from the face of the transducer which is approximately equivalent to the transducer's near field length. Because the last signal maximum occurs at a distance equivalent to the near field, a transducer, by definition, can not be acoustically focused at a distance greater than its near field.

Focus may be designated in three ways:

FPF (Flat Plate Focus) - For an FPF focus, the lens is designed to produce a maximum pulse/echo response from a flat plate target at the distance indicated by the focal length

PTF (Point Target Focus) - For a PTF focus, the lens is designed to produce a maximum pulse/echo response from a small ball target at the distance indicated by the focal length

OLF (Optical Limit Focus) - The OLF designation indicates that the lens is designed according to the lens maker's formula from physical optics and without reference to any operational definition of focal length. The OLF designation describes the lens and ignores diffraction effects.

When focusing a transducer, the type of focus (spherical or cylindrical), focal length, and the focal target (point or flat surface) need to be specified. Based on this information, the radius of curvature of the lens for the transducer which varies based on above parameters, can be calculated . When tested, the measured focal length will be off of the target specified.

There are limitations on focal lengths for transducers of a given frequency and element diameter for a particular focal designation. The maximum practical focal length for a flat plate focus (FPF) is 0.6 times the near field length, and for a point target focus (PTF) the maximum practical focal length is 0.8 times the near field length. Optical limit focus (OLF) focal length is not specifically constrained, but it should be understood that the actual maximum response point from a given target may not correspond to the distance indicated by the OLF focal length.

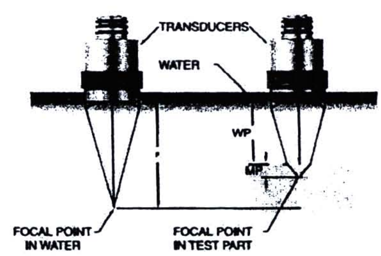
FPF and PTF transducers with focal lengths beyond these maximums, but less than the near field length, will usually be weakly focused units with only a small increase in sensitivity at the focal point. As a practical matter, there may be no functional advantage to a weakly focused transducer over a flat, unfocused transducer. In addition to acoustic limitations on maximum focal lengths, there are mechanical limitations on minimum focal lengths. Consult us for detailed information on focusing parameters.

Table 2 on page 48 lists the near field distances as well as the minimum and maximum practical focal lengths for common frequency-element diameter combinations. Consult us for detailed information in focusing parameters.

Focal Length Variations due to Acoustic Velocity and Geometry of the Test Part

The measured focal length of a transducer is dependent on the material in which it is being measured. This is due to the fact that different materials have different sound velocities. When specifying a transducer's focal length it is typically specified for water. Since most materials have a higher velocity than water, the focal length is effectively shortened. This effect is caused by refraction (according to Snell's Law) and is illustrated in Figure (18).

Fig. 18



This change in the focal length can be predicted by Equation (13).
For example, given a particular focal length and material path, this equation can be used to determine the appropriate water path to compensate for the focusing effect in the test material.

Eqn. 13 $$WP = F - MP(c_{tm}/c_w)$$

WP	=	Water Path
MP	=	Material Depth
F	=	Focal Length in Water
c_{tm}	=	Sound Velocity in the Test Material
c_w	=	Sound Velocity in Water

In addition, the curvature of surface of the test piece can affect focusing. Depending on whether the entry surface is concave or convex, the sound beam may converge more rapidly than it would in a flat sample or it may spread and actually defocus.

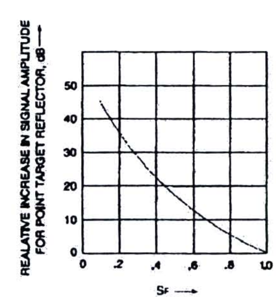
Focusing Gain

Focused immersion transducers use an acoustic lens to effectively shift the location of the Y_0^+ point toward the transducer face. The end result can be a dramatic increase in sensitivity. Figure (19) illustrates the relative increase in signal amplitude from small defects due to focusing where S_F is the normalized focal length and is given by Equation (14). The amplitude from a small defect cannot exceed the echo amplitude from a flat plate.

Eqn. 14 $$S_F = F/N$$

S_F	=	Normalized Focal Length
F	=	Focal Length
N	=	Near Field

Fig. 19



Increase In On-Axis Pulse-Echo Sensitivity Versus Normalized Focal Length

Technical Notes

For example, the chart can be used to determine the increase in on-axis pulse-echo sensitivity of a 2.25 MHz, 1.0" element diameter transducer that is focused at 4 inches. The near field length of this transducer is 9.55", and the normalized focal length is 0.42 (4.0"/9.55"). From the chart it can be seen that this will result in an increase in sensitivity of approximately 21 dB.

Focusing gain (dB) for cylindrical focuses can be estimated as being 3/4 of the gain for spherical focuses.

e. Normal Incidence Shear Wave Transducers

Normal Incidence Shear Wave transducers incorporate a shear wave crystal in a contact transducer case. Rather than using the principles of refraction, as with the angle beam transducers, to produce shear waves in a material, the crystal itself produces the shear wave.

Typically these transducers are used to make shear velocity measurements of materials. This measurement, along with a longitudinal velocity measurement can be used in the calculation of Poisson's Ratio, Young's Modulus, and Shear Modulus. These formulas are listed below for reference.

Eqn. 15
$$\sigma = \frac{1-2\,(V_T/V_L)^2}{2-2\,(V_T/V_L)^2}$$

Eqn. 16
$$E = \frac{V_L^2\rho\,(1+\sigma)(1-2\sigma)}{(1-\sigma)}$$

Eqn. 17
$$G = V_T^2\rho$$

σ = Poisson's Ratio
V_L = Longitudinal Velocity
V_T = Shear (Transverse) Velocity
ρ = Material Density
E = Young's Modulus
G = Shear Modulus

Because shear waves do not propagate in liquids, it is necessary to use a very viscous couplant when making measurements with these. When using this type of transducer in a through transmission mode application, it is important that direction of polarity of each of the transducers is in line with the other. If the polarities are 90° off, the receiver may not receive the signal from the transmitter.

5. TRANSDUCER EXCITATION

As a general rule, all of our ultrasonic transducers are designed for negative spike excitation. The maximum spike excitation voltages should be limited to approximately 50 volts per mil of piezoelectric transducer thickness. Low frequency elements are thick, and high frequency elements are thin. A negative-going 600 volt fast rise time, short duration, spike excitation can be used across the terminals on transducers 5.0 MHz and lower in frequency. For 10 MHz transducers, the voltage used across the terminals should be halved to about 300 volts as measured across the terminals.

Although negative spike excitation is recommended, continuous wave or tone burst excitations may be used. However there are limitations to consider when using these types of excitation. First, the average power dissipation to the transducer should not exceed 125 mW to avoid overheating the transducer and depoling the crystal.

Since total average power depends on a number of factors such as voltage, duty cycle and transducer electrical impedance, the following equations can be used to estimate the maximum excitation duration as well as the number of cycles in a burst to stay within the total power limitation:

Eqn. 18
$$V_{rms} = 1/2(0.707)V_{p\text{-}p}$$

Eqn. 19
$$P_{tot} = \frac{(\text{Duty Cycle})(V_{rms})^2 \cos(\text{phase angle})}{Z}$$

Eqn. 20
$$\text{No. of Cycles in a Burst} = \frac{(\text{Freq.})(\text{Duty Cycle})}{\text{Rep Rate}}$$

Following is an example of how to use the above equations to calculate a duty cycle and number of cycles for a V310-SU transducer.

V310-SU 5.0M Hz, 0.25" element diameter, unfocused
Assuming: 100 V Peak-to-Peak

50 ohm nominal impedance at the transducer input impedance (Note: This value will vary from transducer to transducer and should be measured. An impedance plot can be ordered at the time of purchase if necessary.)
-45° Phase Angle
5 kHz Rep Rate

Step 1: Calculate V_{rms}

$V_{rms}=1/2(0.707)V_{p\text{-}p}$
$V_{rms}=1/2(0.707)(100)=35.35$ V

Step 2: Rearrange Equation (19) to solve for the Duty Cycle. Use 0.125 W as P_{tot}, as this is the maximum recommended for any transducer.

Duty Cycle = $Z{\cdot}P_{tot}/(V_{rms})^2{\cdot}\cos(\text{phase angle})$
= $(50)(0.125)/(35.35)^2{\cdot}(\cos -45°)$
= 0.007s/s

This means 7 milliseconds of excitation in every 1000 milliseconds.

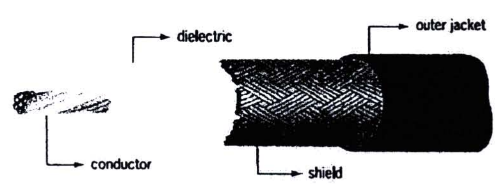
Step 3: Number of cycles in the burst can now be calculated from Equation (20).

No. Of Cycles in Burst = (Freq.)(Duty Cycle) Rep Rate
= $(5{\cdot}10^6){\cdot}(0.007)/(5{\cdot}10^3)$
= 7

6. CABLES

The inside of a cable is made of three main components. They are the conductor, the dielectric, and shield/braid. These components are then surrounded by an outer protective jacket. Figure (20) shows a cross-sectional view of a typical cable. The conductor acts as the positive connection of the cable while the shield acts as the ground. The dielectric isolates the conductor from the shield.

Fig. 20



Most cables have one shielding/braided layer. However, to better prevent electrical interference from the environment double shielded cables have an additional shielding/braided layer in contact with the other.

Technical Notes

The following is a list of standard cable grades we offer:

Type	Grade	Impedance	Nominal Diameter
			inches
15	Low Impedance	15 ohms	0.11
25	Low Impedance	25 ohms	0.10
58	RG58/U	50 ohms	0.20
62	RG62/U	93 ohms	0.24
74	RG174/U	50 ohms	0.11
188	RG188/U	50 ohms	0.11
316	RG316/U	50 ohms	N/A

RG/U is the abbreviation for "radio guide, universal" in the military, 'RG" is the designation for coaxial cable and "U" stands for "general utility". Most of the cables used in ultrasonic NDT have military RG numbers that define the materials, dimensions, and electrical characteristics of the cables.

The characteristic impedance of a coaxial cable is determined by the ratio for the inner diameter of the outer conductor (D) to the outer diameter of the inner conductor (d) and by the dielectric constant (E) of the insulating material between the conductors.

Eqn. 21
$$\text{Impedance } (Zo) = \frac{138}{\sqrt{E}} \text{ Log } (D/d)\,\Omega$$

The characteristic impedance can also be calculated form the capacitance (C) and the inductance (L) per unit length of cable

Eqn. 22
$$\text{Impedance } (Zo) = \sqrt{\frac{L}{C}}$$

The most common values for coaxial cables are 50 ohm, 75 ohm, and 95 ohm. Note that the actual input impedance at a particular frequency may be quite different from the characteristics impedance of the cable due to the impedance of the source and load. In ultrasonics, on transmit the source is the pulser and the load is the transducer; on receive the source is the transducer and the load is the receiver. The complex impedance of the pulser and the transducers will reflect some of the electrical energy at each end of the cable. The amount of reflection is determined by the length of the cable, the frequency of the RF signal, and the electrical impedance of the cable and its termination. In ultrasonic NDT the effect of the cable is most practically determined by experimenting with the shorter and longer cables, with cables of differing impedance, and by placing a 50 ohm feed-through attenuator at the pulser/receiver jack.

Technical Notes

Table 1
Acoustic Properties of Materials

Material	Longitudinal Velocity		Shear Velocity		Acoustic Impedance
	(in/µs)*	(m/s)	(in/µs)*	(m/s)	(Kg/m²s x 10⁶)
Acrylic resin (Perspex®)	0.107	2,730	0.056	1,430	3.22
Aluminum	0.249	6,320	0.123	3,130	17.06
Beryllium	0.508	12,900	0.350	8,880	23.5
Brass, naval	0.174	4,430	0.083	2,120	37.30
Cadmium	0.109	2,780	0.059	1,500	24.02
Columbium	0.194	4,920	0.083	2,100	42.16
Copper	0.183	4,660	0.089	2,260	41.61
Glycerine	0.076	1,920	—	—	2.42
Gold	0.128	3,240	0.047	1,200	62.60
Inconel®	0.229	5,820	0.119	3,020	49.47
Iron	0.232	5,900	0.127	3,230	45.43
Iron, cast					
(slow)	0.138	3,500	0.087	2,200	25.00
(fast)	0.220	5,600	0.126	3,220	40.00
Lead	0.085	2,160	0.028	700	24.49
Manganese	0.183	4,660	0.093	2,350	34.44
Mercury	0.057	1,450	—	—	19.66
Molybdenum	0.246	6,250	0.122	3,350	63.75
Motor Oil (SAE 20 or 30)	0.069	1,740	—	—	1.51
Nickel, pure	0.222	5,630	0.117	2,960	49.99
Platinum	0.156	3,960	0.066	1,670	84.74
Polyamide, (nylon, Perlon®)					
(slow)	0.087	2,200	0.043	1,100	2.40
(fast)	0.102	2,600	0.047	1,200	3.10
Polystyrene	0.092	2,340	—	—	2.47
Polyvinylchloride, PVC, hard	0.094	2,395	0.042	1,060	3.35
Silver	0.142	3,600	0.063	1,590	37.76
Steel, 1020	0.222	5,890	0.128	3,240	45.63
Steel, 4340	0.230	5,850	0.128	3,240	45.63
Steel, 302	0.223	5,660	0.123	3,120	45.45
austenitic stainless Steel, 347	0.226	5,740	0.122	3,090	45.40
austenitic stainless Tin	0.131	3,320	0.066	1,670	24.20
Titanium, Ti 150A	0.240	6,100	0.123	3,120	27.69
Tungsten	0.204	5,180	0.113	2,870	99.72
Uranium	0.133	3,370	0.078	1,980	63.02
Water (20°C)	0.058	1,480	—	—	1.48
Zinc	0.164	4,170	0.095	2,410	29.61
Zirconium	0.183	4,650	0.089	2,250	30.13

* Conversion Factor: 1 m/s = 3.937×10^{-5} in/µS
Source: Nondestructive Testing Handbook 2nd Edition Volume 7
Ultrasonic Testing ASNT 1991 ed Paul McIntire

Near Field Distances of Flat Transducers in Water

The near field values in this table have been determined using the following equation:

$$N = \frac{D^2}{4\lambda}\left[1-\left(\frac{\lambda}{D}\right)^2\right]$$

Note that equations 8 and 8a on page 42 were derived from this expression. The calculations were carried out assuming an ultrasonic velocity in water of 0.586×10^5 in/sec at 22°C and using the actual transducer element diameters. It should be noted that the actual transducer element diameters are slightly smaller than the nominal element diameters listed in the tables in the catalog.
The minimum and maximum practical focal lengths have been calculated by considering the acoustic and mechanical limitations of each configuration. These limitations are a function of transducer frequency, element diameter, and case dimensions. There may be exceptions to the limits listed in the table.

Table 2
Near Field Distance of Flat Transducers in Water

Frequency	Element Diameter	N	Focal Length (PTF)**	
			Min	Max
(MHz)	(inches)	(inches)	(inches)	(inches)
0.5	1.50	4.757	2.15	3.80
	1.125	2.661	1.50	2.10
	1.00	2.095	1.25	1.85
	0.75	1.164	0.78	0.93
1.0	1.50	9.559	2.50	7.85
	1.125	5.366	1.90	4.30
	1.00	4.235	1.625	3.38
	0.75	2.372	1.00	1.90
	0.50	1.043	0.60	0.80
2.25	1.50	21.534	2.70	14.50
	1.125	12.099	2.15	9.50
	1.00	9.554	1.875	7.80
	0.75	5.364	1.00	4.30
	0.50	2.374	0.80	1.90
	0.375	1.329	0.50	1.06
	0.25	0.584	0.35	0.45
3.5	1.00	14.868	1.95	11.5
	0.75	8.350	1.00	6.65
	0.50	3.699	0.83	2.95
	0.375	2.073	0.60	1.65
	0.25	0.914	0.385	0.70
5.0	1.00	21.243	1.95	14.40‡
	0.75	11.932	1.00	8.50
	0.50	5.287	0.75	4.20
	0.375	2.965	0.60	2.35
	0.25	1.309	0.43	1.00
7.5	0.75	17.900	1.00	12.75‡
	0.50	7.933	0.75	6.30‡
10	1.00	42.490	2.00	20.00‡
	0.75	23.868	1.00	15.375‡
	0.50	10.579	0.75	8.40‡
	0.375	5.934	0.60	4.75‡
	0.25	2.622	0.46	2.10
15	0.50	15.870	0.75	11.75‡
	0.375	8.902	0.60	7.10‡
	0.25	3.935	0.50	3.15‡
20	0.25	5.247	0.50	4.20‡
	0.125	1.290	0.25	1.00‡
25	0.25	6.559	0.60	5.25‡

** Panametrics' Standard Case Style, Large Diameter Case Style, Slim Line Case Style, and Pencil Case Style Immersion Transducers with straight connectors (see pages 20-24) can be focused between the Minimum and Maximum Point Target Focal (PTF) distance limits listed in Table 2. Please consult Panametrics before ordering a tranaducer focused outside these limits.

‡ Consideration should be given to attenuation effects which increase linearity and with the square of frequency and the square of bandwidth. In applications where long water paths are required the effects of frequency dependent attenuation should be checked per ASTM E 1065 Annex A7. It is advisable to consider the effects of frequency dependent attenuation if the focal distance equals or exceeds the following values:

Frequency	Focal Length
MHz	Inches
5.0	13
7.5	6
10	3.5
15	1.5
20	0.8
25	0.5
30	0.4

ประวัติผู้วิจัย

ชื่อ : นางสาวขนิษฐา สวัสดี

ชื่อวิทยานิพนธ์ : การสอบเทียบเครื่องมือวัดกำลังของคลื่นอัลตราซาวด์ที่ใช้ในทางการแพทย์

สาขาวิชา : อุปกรณ์การแพทย์

ประวัติ

ประวัติส่วนตัว เกิดเมื่อวันที่ 29 มิถุนายน พ.ศ. 2527 ปัจจุบันอาศัยอยู่บ้านเลขที่ 36 หมู่ 1 ถนนรังสิต-ปทุมธานี ตำบลบ้านกลาง อำเภอเมือง จังหวัดปทุมธานี 12000

ประวัติการศึกษา สำเร็จการศึกษาระดับมัธยมศึกษาตอนต้น และมัธยมศึกษาตอนปลาย จากโรงเรียนคณะราษฎร์บำรุงปทุมธานี จังหวัดปทุมธานี ปีการศึกษา 2546 สำเร็จการศึกษาระดับวิทยาศาสตรบัณฑิต สาขาฟิสิกส์อุตสาหกรรมและอุปกรณ์การแพทย์ จากคณะวิทยาศาสตร์ประยุกต์ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าพระนครเหนือ ปีการศึกษา 2549 และเข้าศึกษาต่อระดับปริญญาโท หลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาอุปกรณ์การแพทย์ บัณฑิตวิทยาลัย มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าพระนครเหนือ ในปี พ.ศ. 2550