# MODEL OPM 2000R TRANSMISSOMETER OPACITY/DUST DENSITY TRANSMITTER

Instruction Bulletin IB-106-200R Revision 1.1

ROSEMOUNT® ANALYTICAL

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# HIGHLIGHTS OF CHANGES

**Effective April, 1998 Rev. 1.0**

| PAGE | SUMMARY |
|---|---|
| All | The revision level changed from Original Issue to Revision 1.0 to distinguish between instruction bulletins released in a preliminary state and the finalized instruction bulletin. |

**Effective February, 1999 Rev. 1.1**

| PAGE | SUMMARY |
|---|---|
| Throughout | Changed NEMA 4X to Type 4X. |
| ii | Add electrical symbols. |
| 1-5 | Modified the user-definable pathlength range. |
| 2-7 | Indicated that power supply 2 (PS2) also supplies power to a status LED. Modified Figure 2-9 to show that JM1 represents the low gain and JM2 represents the high gain. |
| 2-9 | Changed the pathlength range of 20 to 40 ft (6.1 to 12.2 m) to 20 to 26 ft (6.1 to 7.9 m) in Figure 2-12. |
| 3-1 | Illustrated fuse F1 on the IG-1 software board in Figure 3-1. |
| 3-2 | Listed relay jumper blocks in paragraph 3-2.b as components on the HART daughter board. Illustrated fuse F1 on the IG-1 software board in Figure 3-2 and added paragraph 3-2.a.6 discussing the fuse. |
| 3-3 | Modified Figure 3-3 to identify the relay jumper blocks and switches. Added paragraph 3-2.b.8 to discuss the switches. |
| 3-4 | Added paragraph 3-2.b.9 to explain the relay jumper blocks. |
| 3-5 | Added new Figure 3-4 to illustrate the HART daughter board relay contact configurations. |
| 3-6 | Listed relay jumper blocks in paragraph 3-3.b as components on the HART daughter board. Updated figure number and figure number references. Illustrated fuse F1 on the IG-1 software board in Figure 3-5. |
| 3-7 | Updated figure numbers and figure number references. |
| 4-0 | Added note 5 concerning the purge air failure flow switch cable connection. |
| 4-3 | Added the B16.5 designation to the ANSI flange in Figure 4-3. |
| 4-5 | Added four holes (and their dimensions) for customer wiring and added wiring conduit to Figure 4-5. |
| 4-8 | Added temperatures to Figure 4-8 at which the thermostat opens and closes. Corrected the specification reference in paragraph 4-9.a. |
| 4-9 | Added a note concerning the relay jumper blocks on the HART daughter board. |
| 4-10 | Added note 1 to Figure 4-9 (Sheet 1 of 2) concerning the transceiver and retroreflector purge air failure flow switch wiring. |

# HIGHLIGHTS OF CHANGES (Continued)

**Effective February, 1999 Rev. 1.1 (Continued)**

| PAGE | SUMMARY |
|---|---|
| 4-12 | Added note 1 to Figure 4-10 (Sheet 1 of 2) concerning the transceiver and retroreflector purge air failure flow switch wiring. |
| 4-13 | Modified the HART daughter board to identify the relay jumpers and modified the IG-1 software board to identify fuse F1 in Figure 4-10 (sheet 2 of 2). |
| 4-14 | Added a note concerning the relay jumper blocks on the HART daughter board. |
| 6-9 | Added the default setting column to Table 6-6. |
| 6-11 | Updated figure reference in paragraph 6-7.b.1.(c). Added new step 6-7.b.3 and modified new paragraphs 7 and 8 concerning zero jig usage. Renumbered subsequent steps. |
| 6-12 | Added step 6-7.b.12 concerning zero jig usage. Added OCRF information to Table 6-7. |
| 6-15 | Changed the number of neutral density filters from 20 to 30. |
| 6-16 | Changed the number of neutral density filters from 20 to 30. |
| 6-18 | Added a note concerning HART variables assigned the same process variables. |
| 6-19 | Added the *lx/lt* default setting information to paragraph 6-8.c. |
| 6-20 | Updated the relay 4 and relay 5 default setting information in Table 6-12. |
| 6-21 | Added the default setting column to Table 6-13. |
| 6-23 | Added the default setting column to Table 6-15. |
| 6-24 | Added the default setting column to Table 6-16. |
| 6-25 | Added the default setting column to Table 6-17. |
| 6-26 | Added OCRF to the REF. VOLTAGES menu in Figure 6-10 (sheet 1 of 3). |
| 7-5 | Added item 12 to Table 7-2 concerning the stack LON board status LED. |
| 8-10 | Updated the figure number and item number references in paragraphs 8-5.e.2, 3, and 5. |
| 9-1 | Modified the pathlength LF and zero jig ranges in the encode matrix. |
| 9-3 | Updated the pathlength LF, zero jig, and certification and labeling portions of the decode matrix. |
| 9-4 | Updated the figure number references in Table 9-2. |
| 9-5 | Added a second LCW 2 and added descriptive information to the existing LCW 2 in Table 9-4. Also modified the objective lens and zero jig ranges in Table 9-4 and the retroreflector range in Table 9-5. |
| 9-6 | Updated figure number reference for part number 1A97913H03 in Table 9-6. |
| C-2 | Added OCRF at the end of the REF. VOLTAGES parameter list. |

# ROSEMOUNT WARRANTY

Rosemount warrants that the equipment manufactured and sold by it will, upon shipment, be free of defects in workmanship or material. Should any failure to conform to this warranty become apparent during a period of one year after the date of shipment, Rosemount shall, upon prompt written notice from the purchaser, correct such nonconformity by repair or replacement, F.O.B. factory of the defective part or parts. Correction in the manner provided above shall constitute a fulfillment of all liabilities of Rosemount with respect to the quality of the equipment.

**THE FOREGOING WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES OF QUALITY WHETHER WRITTEN, ORAL, OR IMPLIED (INCLUDING ANY WARRANTY OF MERCHANTABILITY OF FITNESS FOR PURPOSE).**

The remedy(ies) provided above shall be purchaser's sole remedy(ies) for any failure of Rosemount to comply with the warranty provisions, whether claims by the purchaser are based in contract or in tort (including negligence).

Rosemount does not warrant equipment against normal deterioration due to environment. Factors such as corrosive gases and solid particulates can be detrimental and can create the need for repair or replacement as part of normal wear and tear during the warranty period.

Equipment supplied by Rosemount Analytical Inc. but not manufactured by it will be subject to the same warranty as is extended to Rosemount by the original manufacturer.

At the time of installation it is important that the required services are supplied to the system and that the electronic controller is set up at least to the point where it is controlling the sensor heater. This will ensure, that should there be a delay between installation and full commissioning that the sensor being supplied with ac power and reference air will not be subjected to component deterioration.

# PURPOSE

The purpose of this manual is to provide a comprehensive understanding of the OPM 2000R Opacity/Dust Density Transmitter components, function, installation, startup, and maintenance. Opacity Transmitter and Dust Density Transmitter both refer to the OPM 2000R instrument. The designation for U.S. applications is Opacity Transmitter and for European applications is Dust Density Transmitter.

The overview presents the basic principles of the Opacity/Dust Density Transmitter along with the system's performance characteristics and components. The remaining sections contain detailed procedures and information necessary for the installation , startup, and servicing of the system.

Before contacting Rosemount concerning any questions, first consult this manual. It describes most situations encountered in your system's operation and details necessary action.

# DEFINITIONS

The following definitions apply to WARNINGS, CAUTIONS, and NOTES found throughout this publication.

**WARNING**

**Highlights an operation or maintenance procedure, practice, condition, statement, etc. If not strictly observed, could result in injury, death, or long-term health hazards of personnel.**

**CAUTION**

**Highlights an operation or maintenance procedure, practice, condition, statement, etc. If not strictly observed, could result in damage to or destruction of equipment, or loss of effectiveness.**

**NOTE**

**Highlights an essential operating procedure, condition, or statement.**

⏚ EARTH GROUND TERMINAL

⊜ PROTECTI E CONDUCTOR TERMINAL

⚠ RIS OF ELECTRICAL SHOC

⚠ ARNING REFER TO INSTRUCTION BULLETIN

# NOTE TO USERS

The number in the lower right corner of each illustration in this publication is a manual illustration number. It is not a part number, and is not related to the illustration in any technical manner.

# IMPORTANT

## SAFETY INSTRUCTIONS FOR THE WIRING AND INSTALLATION OF THIS APPARATUS

**The following safety instructions apply specifically to all EU member states. They should be strictly adhered to in order to assure compliance with the Low Voltage Directive. Non-EU states should also comply with the following unless superseded by local or National Standards.**

1. Adequate earth connections should be made to all earthing points, internal and external, where provided.

2. After installation or troubleshooting, all safety covers and safety grounds must be replaced. The integrity of all earth terminals must be maintained at all times.

3. Mains supply cords should comply with the requirements of IEC227 or IEC245.

4. All wiring shall be suitable for use in an ambient temperature of greater than 75°C.

5. All cable glands used should be of such internal dimensions as to provide adequate cable anchorage.

6. To ensure safe operation of this equipment, connection to the mains supply should only be made through a circuit breaker which will disconnect all circuits carrying conductors during a fault situation. The circuit breaker may also include a mechanically operated isolating switch. If not, then another means of disconnecting the equipment from the supply must be provided and clearly marked as such. Circuit breakers or switches must comply with a recognized standard such as IEC947. All wiring must conform with any local standards.

7. Where equipment or covers are marked with the symbol to the right, hazardous voltages are likely to be present beneath. These covers should only be removed when power is removed from the equipment — and then only by trained service personnel.

8. Where equipment or covers are marked with the symbol to the right, there is a danger from hot surfaces beneath. These covers should only be removed by trained service personnel when power is removed from the equipment. Certain surfaces may remain hot to the touch.

9. Where equipment or covers are marked with the symbol to the right, refer to the Operator Manual for instructions.

10. All graphical symbols used in this product are from one or more of the following standards: EN61010-1, IEC417, and ISO3864.

# BELANGRIJK

**Veiligheidsvoorschriften voor de aansluiting en installatie van dit toestel.**

**De hierna volgende veiligheidsvoorschriften zijn vooral bedoeld voor de EU lidstaten. Hier moet aan gehouden worden om de onderworpenheid aan de Laag Spannings Richtlijn (Low Voltage Directive) te verzekeren. Niet EU staten zouden deze richtlijnen moeten volgen tenzij zij reeds achterhaald zouden zijn door plaatselijke of nationale voorschriften.**

1. Degelijke aardingsaansluitingen moeten gemaakt worden naar alle voorziene aardpunten, intern en extern.

2. Na installatie of controle moeten alle veiligheidsdeksels en -aardingen terug geplaatst worden. Ten alle tijde moet de betrouwbaarheid van de aarding behouden blijven.

3. Voedingskabels moeten onderworpen zijn aan de IEC227 of de IEC245 voorschriften.

4. Alle bekabeling moet geschikt zijn voor het gebruik in omgevingstemperaturen, hoger dan 75°C.

5. Alle wartels moeten zo gedimensioneerd zijn dat een degelijke kabel bevestiging verzekerd is.

6. Om de veilige werking van dit toestel te verzekeren, moet de voeding door een stroomonderbreker gevoerd worden (min 10A) welke alle draden van de voeding moet onderbreken. De stroomonderbreker mag een mechanische schakelaar bevatten. Zoniet moet een andere mogelijkheid bestaan om de voedingsspanning van het toestel te halen en ook duidelijk zo zijn aangegeven. Stroomonderbrekers of schakelaars moeten onderworpen zijn aan een erkende standaard zoals IEC947.

7. Waar toestellen of deksels aangegeven staan met het symbool is er meestal hoogspanning aanwezig. Deze deksels mogen enkel verwijderd worden nadat de voedingsspanning werd afgelegd en enkel door getraind onderhoudspersoneel.

8. Waar toestellen of deksels aangegeven staan met het symbool is er gevaar voor hete oppervlakken. Deze deksels mogen enkel verwijderd worden door getraind onderhoudspersoneel nadat de voedingsspanning verwijderd werd. Sommige oppper-vlakken kunnen 45 minuten later nog steeds heet aanvoelen.

9. Waar toestellen of deksels aangegeven staan met het symbool gelieve het handboek te raadplegen.

10. Alle grafische symbolen gebruikt in dit produkt, zijn afkomstig uit een of meer van devolgende standaards: EN61010-1, IEC417 en ISO3864.

# VIGTIGT

**Sikkerhedsinstruktion for tilslutning og installering af dette udstyr.**

**Følgende sikkerhedsinstruktioner gælder specifikt i alle EU-medlemslande. Instruktionerne skal nøje følges for overholdelse af Lavsspændingsdirektivet og bør også følges i ikke EU-lande medmindre andet er specificeret af lokale eller nationale standarder.**

1. Passende jordforbindelser skal tilsluttes alle jordklemmer, interne og eksterne, hvor disse forefindes.

2. Efter installation eller fejlfinding skal alle sikkerhedsdæksler og jordforbindelser reetableres.

3. Forsyningskabler skal opfylde krav specificeret i IEC227 eller IEC245.

4. Alle ledningstilslutninger skal være konstrueret til omgivelsestemperatur højere end 75° C.

5. Alle benyttede kabelforskruninger skal have en intern dimension, så passende kabelaflastning kan etableres.

6. For opnåelse af sikker drift og betjening skal der skabes beskyttelse mod indirekte berøring gennem afbryder (min. 10A), som vil afbryde alle kredsløb med elektriske ledere i fejlsituation. Afbryderen skal indholde en mekanisk betjent kontakt. Hvis ikke skal anden form for afbryder mellem forsyning og udstyr benyttes og mærkes som sådan. Afbrydere eller kontakter skal overholde en kendt standard som IEC947.

7. Hvor udstyr eller dæksler er mærket med dette symbol, er farlige spændinger normalt forekom-mende bagved. Disse dæksler bør kun afmonteres, når forsyningsspændingen er frakoblet - og da kun af instrueret servicepersonale.

8. Hvor udstyr eller dæksler er mærket med dette symbol, forefindes meget varme overflader bagved. Disse dæksler bør kun afmonteres af instrueret servicepersonale, når forsyningsspænding er frakoblet. Visse overflader vil stadig være for varme at berøre i op til 45 minutter efter frakobling.

9. Hvor udstyr eller dæksler er mærket med dette symbol, se da i betjeningsmanual for instruktion.

10. Alle benyttede grafiske symboler i dette udstyr findes i én eller flere af følgende standarder:- EN61010-1, IEC417 & ISO3864.

# BELANGRIJK

**Veiligheidsinstructies voor de bedrading en installatie van dit apparaat.**

**Voor alle EU lidstaten zijn de volgende veiligheidsinstructies van toepassing. Om aan de geldende richtlijnen voor laagspanning te voldoen dient men zich hieraan strikt te houden. Ook niet EU lidstaten dienen zich aan het volgende te houden, tenzij de lokale wetgeving anders voorschrijft.**

1. Alle voorziene interne- en externe aardaansluitingen dienen op adequate wijze aangesloten te worden.

2. Na installatie,onderhouds- of reparatie werkzaamheden dienen alle beschermdeksels /kappen en aardingen om reden van veiligheid weer aangebracht te worden.

3. Voedingskabels dienen te voldoen aan de vereisten van de normen IEC 227 of IEC 245.

4. Alle bedrading dient geschikt te zijn voor gebruik bij een omgevings temperatuur boven 75°C.

5. Alle gebruikte kabelwartels dienen dusdanige inwendige afmetingen te hebben dat een adequate verankering van de kabel wordt verkregen.

6. Om een veilige werking van de apparatuur te waarborgen dient de voeding uitsluitend plaats te vinden via een meerpolige automatische zekering (min.10A) die **alle** spanningvoerende geleiders verbreekt indien een foutconditie optreedt. Deze automatische zekering mag ook voorzien zijn van een mechanisch bediende schakelaar. Bij het ontbreken van deze voorziening dient een andere als zodanig duidelijk aangegeven mogelijkheid aanwezig te zijn om de spanning van de apparatuur af te schakelen. Zekeringen en schakelaars dienen te voldoen aan een erkende standaard zoals IEC 947.

7. Waar de apparatuur of de beschermdeksels/kappen gemarkeerd zijn met het volgende symbool, kunnen zich hieronder spanning voerende delen bevinden die gevaar op kunnen leveren. Deze beschermdeksels/kappen mogen uitsluitend verwijderd worden door getraind personeel als de spanning is afgeschakeld.

8. Waar de apparatuur of de beschermdeksels/kappen gemarkeerd zijn met het volgende symbool, kunnen zich hieronder hete oppervlakken of onderdelen bevinden. Bepaalde delen kunnen mogelijk na 45 min. nog te heet zijn om aan te raken.

9. Waar de apparatuur of de beschermdeksels/kappen gemarkeerd zijn met het volgende symbool, dient men de bedieningshandleiding te raadplegen.

10. Alle grafische symbolen gebruikt bij dit produkt zijn volgens een of meer van de volgende standaarden: EN 61010-1, IEC 417 & ISO 3864.

# TÄRKEÄÄ

**Turvallisuusohje, jota on noudatettava tämän laitteen asentamisessa ja kaapeloinnissa.**

**Seuraavat ohjeet pätevät erityisesti EU:n jäsenvaltioissa. Niitä täytyy ehdottomasti noudattaa jotta täytettäisiin EU:n matalajännitedirektiivin (Low Voltage Directive) yhteensopivuus. Myös EU:hun kuulumattomien valtioiden tulee nou-dattaa tätä ohjetta, elleivät kansalliset standardit estä sitä.**

1. Riittävät maadoituskytkennät on tehtävä kaikkiin maadoituspisteisiin, sisäisiin ja ulkoisiin.

2. Asennuksen ja vianetsinnän jälkeen on kaikki suojat ja suojamaat asennettava takaisin paikoilleen. Maadoitusliittimen kunnollinen toiminta täytyy aina ylläpitää.

3. Jännitesyöttöjohtimien täytyy täyttää IEC227 ja IEC245 vaatimukset.

4. Kaikkien johdotuksien tulee toimia >75°C lämpötiloissa.

5. Kaikkien läpivientiholkkien sisähalkaisijan täytyy olla sellainen että kaapeli lukkiutuu kunnolla kiinni.

6. Turvallisen toiminnan varmistamiseksi täytyy jännitesyöttö varustaa turvakytkimellä (min 10A), joka kytkee irti kaikki jännitesyöttöjohtimet vikatilanteessa. Suojaan täytyy myös sisältyä mekaaninen erotuskytkin. Jos ei, niin jännitesyöttö on pystyttävä katkaisemaan muilla keinoilla ja merkittävä siten että se tunnistetaan sellaiseksi. Turvakytkimien tai katkaisimien täytyy täyttää IEC947 standardin vaatimukset näkyvyydestä.

7. Mikäli laite tai kosketussuoja on merkitty tällä merkillä on merkinnän takana tai alla hengenvaarallisen suuruinen jännite. Suojaa ei saa poistaa jänniteen ollessa kytkettynä laitteeseen ja poistamisen saa suorittaa vain alan asian-tuntija.

8. Mikäli laite tai kosketussuoja on merkitty tällä merkillä on merkinnän takana tai alla kuuma pinta. Suojan saa poistaa vain alan asiantuntija kun jännite-syöttö on katkaistu. Tällainen pinta voi säilyä kosketuskuumana jopa 45 mi-nuuttia.

9. Mikäli laite tai kosketussuoja on merkitty tällä merkillä katso lisäohjeita käyt-töohjekirjasta

10. Kaikki tässä tuotteessa käytetyt graafiset symbolit ovat yhdestä tai useammasta seuraavis-ta standardeista: EN61010-1, IEC417 & ISO3864.

# IMPORTANT

**Consignes de sécurité concernant le raccordement et l'installation de cet appareil.**

**Les consignes de sécurité ci-dessous s'adressent particulièrement à tous les états membres de la communauté européenne. Elles doivent être strictement appliquées afin de satisfaire aux directives concernant la basse tension. Les états non membres de la communauté européenne doivent également appliquer ces consignes sauf si elles sont en contradiction avec les standards locaux ou nationaux.**

1. Un raccordement adéquat à la terre doit être effectuée à chaque borne de mise à la terre, interne et externe.

2. Après installation ou dépannage, tous les capots de protection et toutes les prises de terre doivent être remis en place, toutes les prises de terre doivent être respectées en permanence.

3. Les câbles d'alimentation électrique doivent être conformes aux normes IEC227 ou IEC245

4. Tous les raccordements doivent pouvoir supporter une température ambiante supérieure à 75°C.

5. Tous les presse-étoupes utilisés doivent avoir un diamètre interne en rapport avec les câbles afin d'assurer un serrage correct sur ces derniers.

6. Afin de garantir la sécurité du fonctionnement de cet appareil, le raccordement à l'alimentation électrique doit être réalisé exclusivement au travers d'un disjoncteur (minimum 10A.) isolant tous les conducteurs en cas d'anomalie. Ce disjoncteur doit également pouvoir être actionné manuellement, de façon mécanique. Dans le cas contraire, un autre système doit être mis en place afin de pouvoir isoler l'appareil et doit être signalisé comme tel. Disjoncteurs et interrupteurs doivent être conformes à une norme reconnue telle IEC947.

7. Lorsque les équipements ou les capots affichent le symbole suivant, cela signifie que des tensions dangereuses sont présentes. Ces capots ne doivent être démontés que lorsque l'alimentation est coupée, et uniquement par un personnel compétent.

8. Lorsque les équipements ou les capots affichent le symbole suivant, cela signifie que des surfaces dangereusement chaudes sont présentes. Ces capots ne doivent être démontés que lorsque l'alimentation est coupée, et uniquement par un personnel compétent. Certaines surfaces peuvent rester chaudes jusqu'à 45 mn.

9. Lorsque les équipements ou les capots affichent le symbole suivant, se reporter au manuel d'instructions.

10. Tous les symboles graphiques utilisés dans ce produit sont conformes à un ou plusieurs des standards suivants: EN61010-1, IEC417 & ISO3864.

# Wichtig

**Sicherheitshinweise für den Anschluß und die Installation dieser Geräte.**

**Die folgenden Sicherheitshinweise sind in allen Mitgliederstaaten der europäischen Gemeinschaft gültig. Sie müssen strickt eingehalten werden, um der Niederspannungsrichtlinie zu genügen. Nichtmitgliedsstaaten der europäischen Gemeinschaft sollten die national gültigen Normen und Richtlinien einhalten.**

1. Alle intern und extern vorgesehenen Erdungen der Geräte müssen ausgeführt werden.

2. Nach Installation, Reparatur oder sonstigen Eingriffen in das Gerät müssen alle Sicherheitsabdeckungen und Erdungen wieder installiert werden. Die Funktion aller Erdverbindungen darf zu keinem Zeitpunkt gestört sein.

3. Die Netzspannungsversorgung muß den Anforderungen der IEC227 oder IEC245 genügen.

4. Alle Verdrahtungen sollten mindestens bis 75 °C ihre Funktion dauerhaft erfüllen.

5. Alle Kabeldurchführungen und Kabelverschraubungen sollten in Ihrer Dimensionierung so gewählt werden, daß diese eine sichere Verkabelung des Gerätes ermöglichen.

6. Um eine sichere Funktion des Gerätes zu gewährleisten, muß die Spannungsversorgung über mindestens 10 A abgesichert sein. Im Fehlerfall muß dadurch gewährleistet sein, daß die Spannungsversorgung zum Gerät bzw. zu den Geräten unterbrochen wird. Ein mechanischer Schutzschalter kann in dieses System integriert werden. Falls eine derartige Vorrichtung nicht vorhanden ist, muß eine andere Möglichkeit zur Unterbrechung der Spannungszufuhr gewährleistet werden mit Hinweisen deutlich gekennzeichnet werden. Ein solcher Mechanismus zur Spannungsunterbrechung muß mit den Normen und Richtlinien für die allgemeine Installation von Elektrogeräten, wie zum Beispiel der IEC947, übereinstimmen.

7. Mit dem Symbol sind Geräte oder Abdeckungen gekennzeichnet, die eine gefährliche (Netzspannung) Spannung führen. Die Abdeckungen dürfen nur entfernt werden, wenn die Versorgungsspannung unterbrochen wurde. Nur geschultes Personal darf an diesen Geräten Arbeiten ausführen.

8. Mit dem Symbol sind Geräte oder Abdeckungen gekennzeichnet, in bzw. unter denen heiße Teile vorhanden sind. Die Abdeckungen dürfen nur entfernt werden, wenn die Versorgungsspannung unterbrochen wurde. Nur geschultes Personal darf an diesen Geräten Arbeiten ausführen. Bis 45 Minuten nach dem Unterbrechen der Netzzufuhr können derartig Teile noch über eine erhöhte Temperatur verfügen.

9. Mit dem Symbol sind Geräte oder Abdeckungen gekennzeichnet, bei denen vor dem Eingriff die entsprechenden Kapitel im Handbuch sorgfältig durchgelesen werden müssen.

10. Alle in diesem Gerät verwendeten graphischen Symbole entspringen einem oder mehreren der nachfolgend aufgeführten Standards: EN61010-1, IEC417 & ISO3864.

# IMPORTANTE

**Norme di sicurezza per il cablaggio e l'installazione dello strumento.**

**Le seguenti norme di sicurezza si applicano specificatamente agli stati membri dell'Unione Europea, la cui stretta osservanza è richiesta per garantire conformità alla Direttiva del Basso Voltaggio. Esse si applicano anche agli stati non appartenenti all'Unione Europea, salvo quanto disposto dalle vigenti normative locali o nazionali**.

1. Collegamenti di terra idonei devono essere eseguiti per tutti i punti di messa a terra interni ed esterni, dove previsti.

2. Dopo l'installazione o la localizzazione dei guasti, assicurarsi che tutti i coperchi di protezione siano stati collocati e le messa a terra siano collegate. L'integrità di ciscun morsetto di terra deve essere costantemente garantita.

3. I cavi di alimentazione della rete devono essere secondo disposizioni IEC227 o IEC245.

4. L'intero impianto elettrico deve essere adatto per uso in ambiente con temperature superiore a 75°C.

5. Le dimensioni di tutti i connettori dei cavi utilizzati devono essere tali da consentire un adeguato ancoraggio al cavo.

6. Per garantire un sicuro funzionamento dello strumento il collegamento alla rete di alimentazione principale dovrà essere eseguita tramite interruttore automatico (min.10A), in grado di disattivare tutti i conduttori di circuito in caso di guasto. Tale interruttore dovrà inoltre prevedere un sezionatore manuale o altro dispositivo di interruzione dell'alimentazione, chiaramente identificabile. Gli interruttori dovranno essere conformi agli standard riconosciuti, quali IEC947.

7. Il simbolo riportato sullo strumento o sui coperchi di protezione indica probabile presenza di elevati voltaggi. Tali coperchi di protezione devono essere rimossi esclusivamente da personale qualificato, dopo aver tolto alimentazione allo strumento.

8. Il simbolo riportato sullo strumento o sui coperchi di protezione indica rischio di contatto con superfici ad alta temperatura. Tali coperchi di protezione devono essere rimossi esclusivamente da personale qualificato, dopo aver tolto alimentazione allo strumento. Alcune superfici possono mantenere temperature elevate per oltre 45 minuti.

9. Se lo strumento o il coperchio di protezione riportano il simbolo, fare riferimento alle istruzioni del manuale Operatore.

10. Tutti i simboli grafici utilizzati in questo prodotto sono previsti da uno o più dei seguenti standard: EN61010-1, IEC417 e ISO3864.

# VIKTIG

**Sikkerhetsinstruks for tilkobling og installasjon av dette utstyret.**

**Følgende sikkerhetsinstruksjoner gjelder spesifikt alle EU medlemsland og land med i EØS-avtalen. Instruksjonene skal følges nøye slik at installasjonen blir i henhold til lavspenningsdirektivet. Den bør også følges i andre land, med mindre annet er spesifisert av lokale- eller nasjonale standarder.**

1. Passende jordforbindelser må tilkobles alle jordingspunkter, interne og eksterne hvor disse forefinnes.

2. Etter installasjon eller feilsøking skal alle sikkerhetsdeksler og jordforbindelser reetableres. Jordingsforbindelsene må alltid holdes i god stand.

3. Kabler fra spenningsforsyning skal oppfylle kravene spesifisert i IEC227 eller IEC245.

4. Alle ledningsforbindelser skal være konstruert for en omgivelsestemperatur høyere en 750C.

5. Alle kabelforskruvninger som benyttes skal ha en indre dimensjon slik at tilstrekkelig avlastning oppnåes.

6. For å oppnå sikker drift og betjening skal forbindelsen til spenningsforsyningen bare skje gjennom en strømbryter (minimum 10A) som vil bryte spenningsforsyningen til alle elektriske kretser ved en feilsituasjon. Strømbryteren kan også inneholde en mekanisk operert bryter for å isolere instrumentet fra spenningsforsyningen. Dersom det ikke er en mekanisk operert bryter installert, må det være en annen måte å isolere utstyret fra spenningsforsyningen, og denne måten må være tydelig merket. Kretsbrytere eller kontakter skal oppfylle kravene i en annerkjent standard av typen IEC947 eller tilsvarende.

7. Der hvor utstyr eller deksler er merket med symbol for farlig spenning, er det sannsynlig at disse er tilstede bak dekslet. Disse dekslene må bare fjærnes når spenningsforsyning er frakoblet utstyret, og da bare av trenet servicepersonell.

8. Der hvor utstyr eller deksler er merket med symbol for meget varm overflate, er det sannsynlig at disse er tilstede bak dekslet. Disse dekslene må bare fjærnes når spenningsforsyning er frakoblet utstyret, og da bare av trenet servicepersonell. Noen overflater kan være for varme til å berøres i opp til 45 minutter etter spenningsforsyning frakoblet.

9. Der hvor utstyret eller deksler er merket med symbol, vennligst referer til instruksjonsmanualen for instrukser.

10. Alle grafiske symboler brukt i dette produktet er fra en eller flere av følgende standarder: EN61010-1, IEC417 & ISO3864.

# IMPORTANTE

**Instruções de segurança para ligação e instalação deste aparelho.**

**As seguintes instruções de segurança aplicam-se especificamente a todos os estados membros da UE. Devem ser observadas rigidamente por forma a garantir o cumprimento da Directiva sobre Baixa Tensão. Relativamente aos estados que não pertençam à UE, deverão cumprir igualmente a referida directiva, exceptuando os casos em que a legislação local a tiver substituído.**

1. Devem ser feitas ligações de terra apropriadas a todos os pontos de terra, internos ou externos.

2. Após a instalação ou eventual reparação, devem ser recolocadas todas as tampas de segurança e terras de protecção. Deve manter-se sempre a integridade de todos os terminais de terra.

3. Os cabos de alimentação eléctrica devem obedecer às exigências das normas IEC227 ou IEC245.

4. Os cabos e fios utilizados nas ligações eléctricas devem ser adequados para utilização a uma temperatura ambiente até 75º C.

5. As dimensões internas dos bucins dos cabos devem ser adequadas a uma boa fixação dos cabos.

6. Para assegurar um funcionamento seguro deste equipamento, a ligação ao cabo de alimentação eléctrica deve ser feita através de um disjuntor (min. 10A) que desligará todos os condutores de circuitos durante uma avaria. O disjuntor poderá também conter um interruptor de isolamento accionado manualmente. Caso contrário, deverá ser instalado qualquer outro meio para desligar o equipamento da energia eléctrica, devendo ser assinalado convenientemente. Os disjuntores ou interruptores devem obedecer a uma norma reconhecida, tipo IEC947.

7. Sempre que o equipamento ou as tampas contiverem o símbolo, é provável a existência de tensões perigosas. Estas tampas só devem ser retiradas quando a energia eléctrica tiver sido desligada e por Pessoal da Assistência devidamente treinado.

8. Sempre que o equipamento ou as tampas contiverem o símbolo, há perigo de existência de superfícies quentes. Estas tampas só devem ser retiradas por Pessoal da Assistência devidamente treinado e depois de a energia eléctrica ter sido desligada. Algumas superfícies permanecem quentes até 45 minutos depois.

9. Sempre que o equipamento ou as tampas contiverem o símbolo, o Manual de Funcionamento deve ser consultado para obtenção das necessárias instruções.

10. Todos os símbolos gráficos utilizados neste produto baseiam-se em uma ou mais das seguintes normas: EN61010-1, IEC417 e ISO3864.

# IMPORTANTE

**Instrucciones de seguridad para el montaje y cableado de este aparato.**

**Las siguientes instrucciones de seguridad , son de aplicacion especifica a todos los miembros de la UE y se adjuntaran para cumplir la normativa europea de baja tension.**

1. Se deben preveer conexiones a tierra del equipo, tanto externa como internamente, en aquellos terminales previstos al efecto.

2. Una vez finalizada las operaciones de mantenimiento del equipo, se deben volver a colocar las cubiertas de seguridad aasi como los terminales de tierra. Se debe comprobar la integridad de cada terminal.

3. Los cables de alimentacion electrica cumpliran con las normas IEC 227 o IEC 245.

4. Todo el cableado sera adecuado para una temperatura ambiental de 75ºC.

5. Todos los prensaestopas seran adecuados para una fijacion adecuada de los cables.

6. Para un manejo seguro del equipo, la alimentacion electrica se realizara a traves de un interruptor magnetotermico ( min 10 A ), el cual desconectara la alimentacion electrica al equipo en todas sus fases durante un fallo. Los interruptores estaran de acuerdo a la norma IEC 947 u otra de reconocido prestigio.

7. Cuando las tapas o el equipo lleve impreso el simbolo de tension electrica peligrosa, dicho alojamiento solamente se abrira una vez que se haya interrumpido la alimentacion electrica al equipo asimismo la intervencion sera llevada a cabo por personal entrenado para estas labores.

8. Cuando las tapas o el equipo lleve impreso el simbolo, hay superficies con alta temperatura, por tanto se abrira una vez que se haya interrumpido la alimentacion electrica al equipo por personal entrenado para estas labores, y al menos se esperara unos 45 minutos para enfriar las superficies calientes.

9. Cuando el equipo o la tapa lleve impreso el simbolo, se consultara el manual de instrucciones.

10. Todos los simbolos graficos usados en esta hoja, estan de acuerdo a las siguientes normas EN61010-1, IEC417 & ISO 3864.

# VIKTIGT

**Säkerhetsföreskrifter för kablage och installation av denna apparat.**

**Följande säkerhetsföreskrifter är tillämpliga för samtliga EU-medlemsländer. De skall följas i varje avseende för att överensstämma med Lågspännings direktivet. Icke EU medlemsländer skall också följa nedanstående punkter, såvida de inte övergrips av lokala eller nationella föreskrifter.**

1. Tillämplig jordkontakt skall utföras till alla jordade punkter, såväl internt som externt där så erfordras.

2. Efter installation eller felsökning skall samtliga säkerhetshöljen och säkerhetsjord återplaceras. Samtliga jordterminaler måste hållas obrutna hela tiden.

3. Matningsspänningens kabel måste överensstämma med föreskrifterna i IEC227 eller IEC245.

4. Allt kablage skall vara lämpligt för användning i en omgivningstemperatur högre än 75ºC.

5. Alla kabelförskruvningar som används skall ha inre dimensioner som motsvarar adekvat kabelförankring.

6. För att säkerställa säker drift av denna utrustning skall anslutning till huvudströmmen endast göras genom en säkring (min 10A) som skall frånkoppla alla strömförande kretsar när något fel uppstår. Säkringen kan även ha en mekanisk frånskiljare. Om så inte är fallet, måste ett annat förfarande för att frånskilja utrustningen från strömförsörjning tillhandahållas och klart framgå genom markering. Säkring eller omkopplare måste överensstämma med en gällande standard såsom t ex IEC947.

7. Där utrustning eller hölje är markerad med vidstående symbol föreliggerisk för livsfarlig spänning i närheten. Dessa höljen får endast avlägsnas när strömmen ej är ansluten till utrustningen - och då endast av utbildad servicepersonal.

8. När utrustning eller hölje är markerad med vidstående symbol föreligger risk för brännskada vid kontakt med uppvärmd yta. Dessa höljen får endast avlägsnas av utbildad servicepersonal, när strömmen kopplats från utrustningen. Vissa ytor kan vara mycket varma att vidröra även upp till 45 minuter efter avstängning av strömmen.

9. När utrustning eller hölje markerats med vidstående symbol bör instruktionsmanualen studeras för information.

10. Samtliga grafiska symboler som förekommer i denna produkt finns angivna i en eller flera av följande föreskrifter:- EN61010-1, IEC417 & ISO3864.

# ΠΡΟΣΟΧΗ

**Οδηγίες ασφαλείας για την καλωδίωση και εγκατάσταση της συσκευής.**

**Οι ακόλουθες οδηγίες ασφαλείας εφαρμόζονται ειδικά σε όλες τις χώρες μέλη της Ευρωπαϊκής Κοινότητας. Θα πρέπει να ακολουθούνται αυστηρά ώστε να εξασφαλιστεί η συμβατότητα με τις οδηγίες για τη Χαμηλή Τάση. Χώρες που δεν είναι μέλη της Ευρωπαϊκής Κοινότητας θα πρέπει επίσης να ακολουθούν τις οδηγίες εκτός εάν αντικαθίστανται από τα Τοπικά ή Εθνικά Πρότυπα.**

1. Επαρκείς συνδέσεις γείωσης θα πρέπει να γίνονται σε όλα τα σημεία γείωσης, εσωτερικά και εξωτερικά όπου υπάρχουν.

2. Μετά την εγκατάσταση ή την εκσφαλμάτωση όλα τα καλύματα ασφαλείας και οι γειώσεις ασφαλείας πρέπει να επανεγκαθίστανται. Η καλή κατάσταση όλων των ακροδεκτών γείωσης πρέπει να ελέγχεται και να συντηρείται διαρκώς.

3. Τα καλώδια τροφοδοσίας πρέπει να πληρούν τις απαιτήσεις των IEC227 ή IEC245.

4. Ολες οι καλωδιώσεις θα πρέπει είναι κατάλληλες για χρήση σε ατμοσφαιρική θερμοκρασία χώρου υψηλότερη από 75°C.

5. Ολοι οι στυπιοθλίπτες θα πρέπει να είναι τέτοιων εσωτερικών διαστάσεων ώστε να παρέχουν επαρκή στερέωση των καλωδίων.

6. Για τη διασφάλιση ασφαλούς λειτουργίας της σύνδεσης τροφοδοσίας αυτής της συσκευής θα πρέπει να γίνεται μόνο μέσω ασφαλειοδιακόπτη (ελάχιστο 10A) ο οποίος θα αποσυνδέει όλους του ηλεκτροφόρους αγωγούς στη διάρκεια κατάστασης σφάλματος.
   Ο ασφαλειοδιακόπτης μπορεί επίσης να περιλαμβάνει μηχανικό διακόπτη απομόνωσης. Εάν δεν περιλαμβάνει, τότε άλλα μέσα αποσύνδεσης της συσκευής από την τροφοδοσία πρέπει να παροχηθούν και σαφώς να σημανθούν σαν τέτοια. Οι ασφαλειοδιακόπτες ή διακόπτες πρέπει να συμφωνούν με αναγνωρισμένα πρότυπα όπως το IEC947.

7. Οπου συσκευές ή καλύματα είναι σημασμένα με το σύμβολο επικίνδυνες τάσεις ενυπάρχουν κάτω από αυτά.
   Αυτά τα καλύματα θα πρέπει να αφαιρούνται μόνο όταν έχει αφαιρεθεί η τροφοδοσία από τη συσκευή και τότε μόνο από ειδικευμένο τεχνικό προσωπικό.

8. Οπου συσκευές ή καλύματα είναι σημασμένα με το σύμβολο υπάρχει κίνδυνος από καυτές επιφάνειες κάτω από αυτά.
   Αυτά τα καλύματα θα πρέπει να αφαιρούνται μόνο από ειδικευμένο τεχνικό προσωπικό, όταν η τροφοδοσία έχει αφαιρεθεί από από τη συσκευή. Τέτοιες επιφάνειες μπορούν να παραμείνουν ζεστές στην αφή έως και 45 λεπτά αργότερα.

9. Οπου συσκευές ή καλύματα είναι σημασμένα με το σύμβολο αναφερθείται στις οδηγίες χρήσης της συσκευής.

10. Ολα τα γραφικά σύμβολα που χρησιμοποιούνται σε αυτό το προϊόν είναι από ένα ή περισσότερα από τα έχης πρότυπα: **EN61010-1, IEC417** και **ISO3864.**

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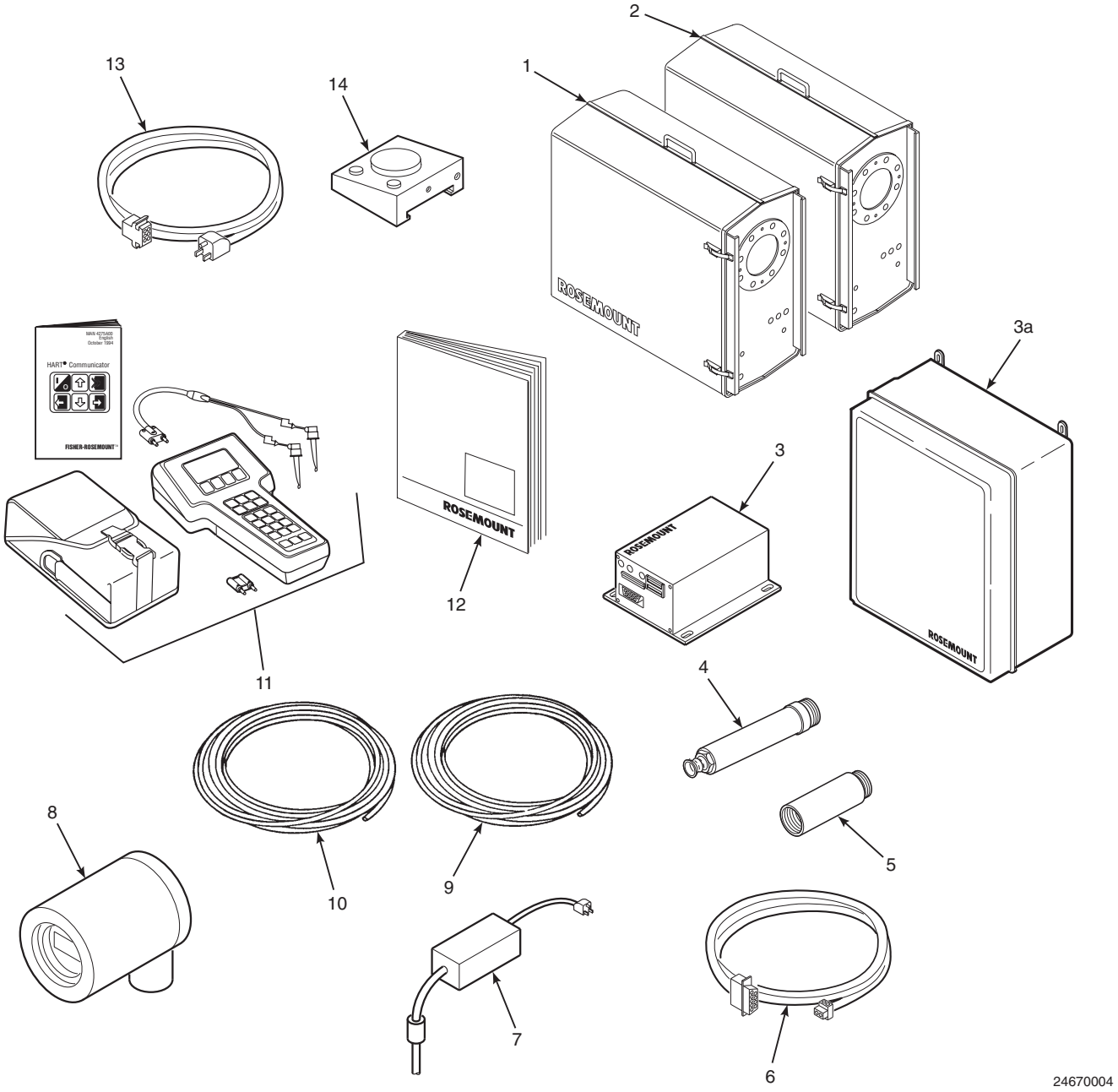



| ITEM | DESCRIPTION | ITEM | DESCRIPTION |
|---|---|---|---|
| 1 | Transceiver Module | 8 | 751 Field Signal Indicator (optional) |
| 2 | Retroreflector Module | 9 | Communication Cable (optional) |
| 3 | General Purpose Intelligent Electronics | 10 | Purge Air Failure Flow Switch Cable (optional) |
| 3a | Type 4X Intelligent Electronics (optional) | 11 | HART® Communications Package (optional) |
| 4 | Optical Alignment Sight (optional) | 12 | Instruction Bulletin |
| 5 | 6 in. Optical Extension (optional) | 13 | Power Test Cable |
| 6 | LON Communication Test Cable | 14 | Zero Jig (optional) |
| 7 | Power Supply (optional) | | |

**Figure 1-1. Standard Model OPM 2000R Transmissometer Opacity/Dust Density Transmitter**

# SECTION I. SYSTEM OVERVIEW

**1-1. COMPONENT CHECKLIST OF TYPICAL SYSTEM (PACKAGE CONTENTS).** A typical Rosemount Model OPM 2000R Transmissometer Opacity/Dust Density Transmitter should contain the items shown in Figure 1-1.

**1-2. SYSTEM OVERVIEW.**

**a. Scope**. This instruction bulletin is designed to supply details needed to install, operate, and maintain an OPM 2000R.

**b. Reason for Measuring Opacity.** Opacity refers to the amount of light being scattered or absorbed by particles in the light beam path. An opacity or dust density transmitter (also called a transmissometer) measures the particulate level of stack emissions. One of the most common reasons for measuring opacity is to comply with Environmental Protection Agency (EPA) or other national requirements. Federal regulations for new emission sources and many state regulations for both new and existing sources specify maximum limits for stack emission opacity.

A transmissometer can be used in a variety of applications. Those applications include monitoring the efficiency of emission control systems, detecting broken bags in baghouses, and determining the time rapping cycles for electrostatic precipitators. Another application is to gauge the effectiveness of injecting flue gas conditioning agents used to improve electrostatic precipitator performance.

Opacity data can also serve as a rough indicator of combustion efficiency. Extreme changes in opacity may indicate inefficient combustion or boiler problems. Because the transmitter gives accurate, immediate-response data, corrective actions can be taken as soon as problems occur. This data serves not only the compliance requirement of pollution regulation standards but also as a means to achieve improved efficiency and operating profit.

Originally, a trained smoke reader determined the particulate level of stack emissions solely by observation. The opacity of the plume was judged in reference to a standard Ringelmann scale of 0 to 5. These determinations tended to be influenced by several sources of error such as sky haze, sun position, and the subjective determination of the observer. These sources of error, especially at lower opacity levels, can produce highly variable readings even when performed by a trained observer.

**c. System Description.** The OPM 2000R is an in situ optical transmitter that uses a visible light beam in the photopic region (peak and mean responses in the 500 to 600 nm range) to measure opacity in stack emissions. The OPM 2000R contains no moving parts except for blower motors, which eliminates sources of wear and possible failure.

Federal regulations and many state and local laws use visual observation as a reference. Thus, for a true correlation, it is important that transmissometers use the same spectral response range as the human eye. This portion of the spectrum is called the photopic response range. Since visual readings are taken at the stack exit, the OPM 2000R compensates for the difference between stack diameter at the exit and stack diameter at the installation site.

The OPM 2000R consists of a transmitter/ receiver (transceiver) module, a retroreflector module, and intelligent electronics. The transceiver and retroreflector modules are mounted directly opposite of each other on the stack (Figure 1-2). The transceiver projects a controlled beam of light across the stack. The corner cube bounces the light back along a parallel path to the transceiver. Particles in the gas stream cause a certain amount of the light to be scattered and absorbed. This amount varies depending upon the particulate content of the gas stream and the particle type and size.

The light then strikes a detector, which converts the light into a voltage that can be processed. The detector signal is amplified by an independently powered detector/amplifier board. The amplified signal is then digitized and transmitted to the intelligent electronics. The intelligent electronics calculates opacity, sends commands to the transceiver, and provides an operator interface via HART communications.

Because the beam passes through the stack twice (once in each direction), the resulting value is a double-pass transmittance measurement. By passing through the smoke twice, sensitivity to low opacity levels is increased.

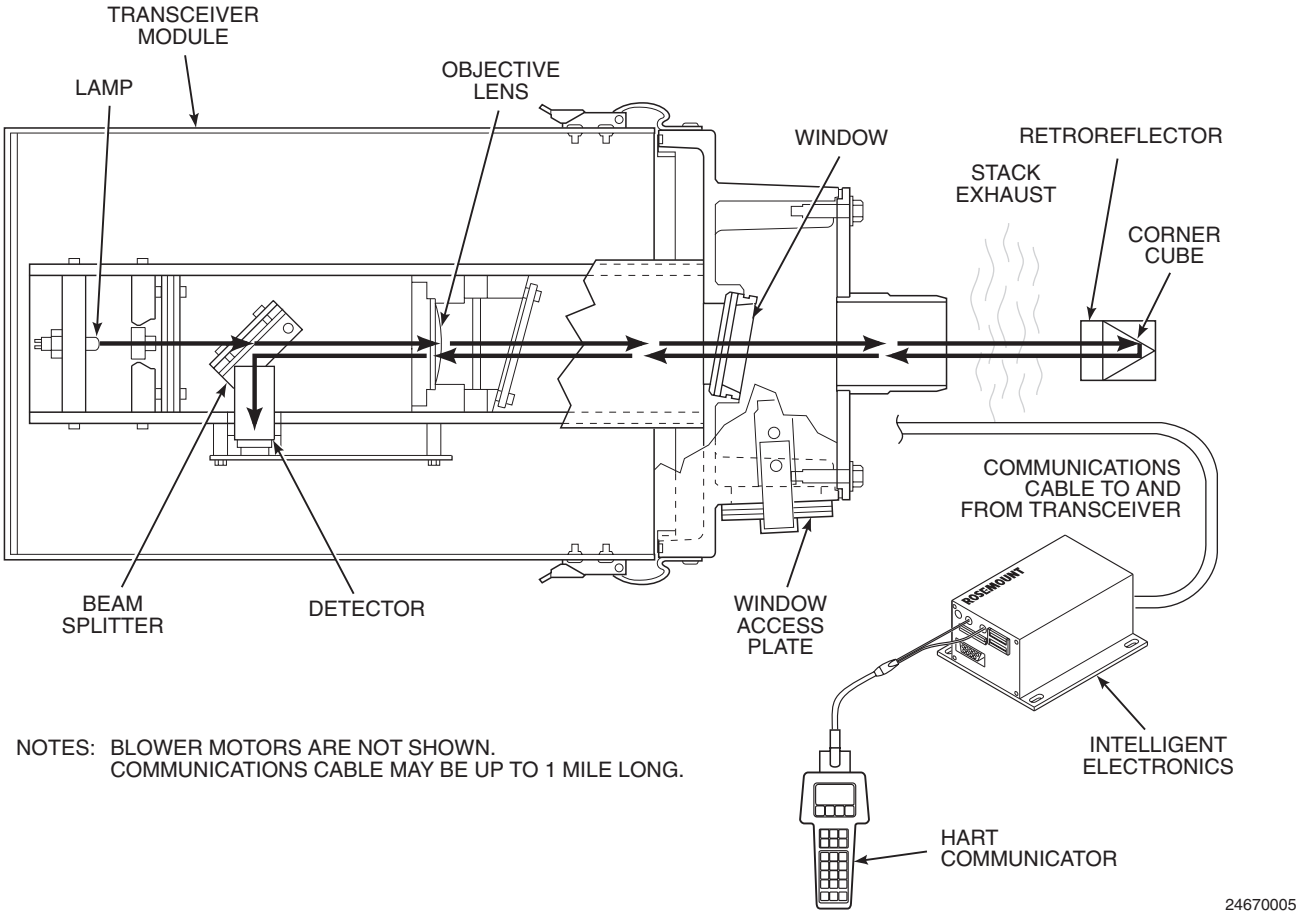



**Figure 1-2. Component Relationships**

The measurement value is compared to a reference value previously determined with no smoke in the light path. The resulting ratio is the transmittance value for the measurement path. This ratio can then be converted to units of optical density, stack exit opacity, and dust concentration.

The reference value depends on the *lf* dimension shown in Figure 1-3. Also illustrated are dimensions *lx* and *lt*, which are necessary for OPM 2000R calibration and setup. These dimensions are defined as follows:

*lx* = inside stack diameter at stack exit.

*lt* = inside stack diameter at the transmitter location.

*lf* = flange to flange distance between the transceiver and retroreflector unit. It is also the distance that must be used to calibrate the unit offline.

The LX/LT parameter is entered in the BASIC SETUP sub-menu of the HART Communicator. See paragraph 6-8.c for more information.

Opacity is a complementary function of transmittance. It is a measurement of the amount of light that is blocked or absorbed by the flue gases. The measurement of smoke opacity is also sometimes referred to in Ringelmann numbers. By definition, Ringelmann No. 1 is equivalent to 20% opacity with the opacity increasing 20% for each subsequent number. This scale is based on a single-pass value as would be read by a human observer.

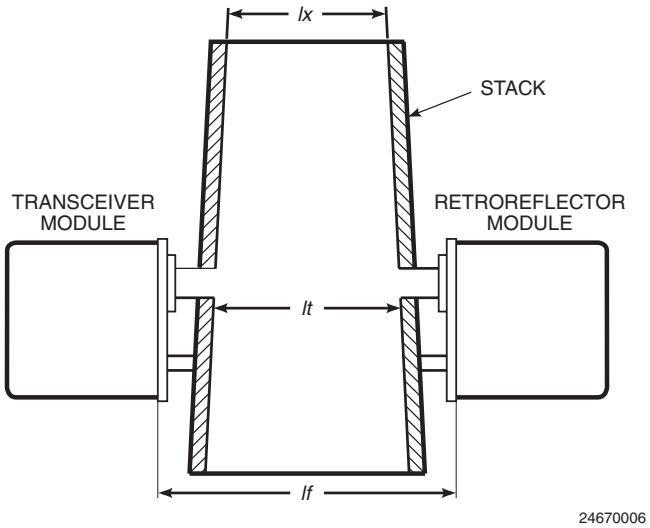



**Figure 1-3. Calibration Dimensions**

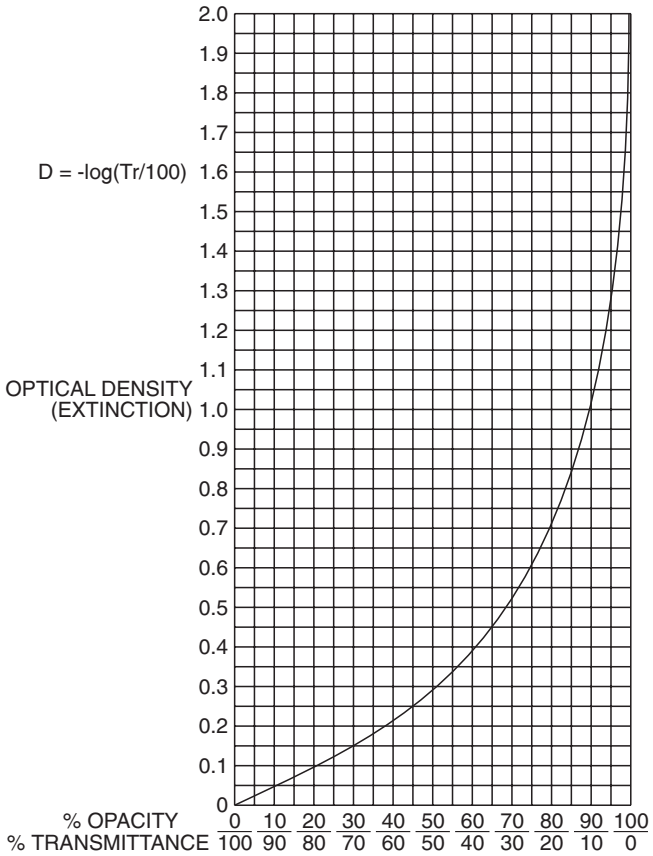



**Figure 1-4. Relationship of Opacity, Transmittance, and Optical Density**

The relationship between opacity, transmittance, and optical density (or extinction) is shown graphically in Figure 1-4 and in the table in Appendix A. One hundred percent transmittance is equivalent to 0% opacity or zero optical density. Opacity and optical density are logarithmically related in such a way that zero optical density equals zero opacity; an optical density of one is equal to 90% opacity; an optical density of two is equal to 99% opacity, etc.

The OPM 2000R automatically compensates for the effects of ambient light, zero drift, and component aging with every measurement cycle. Four separate voltages produced in each measurement cycle are compared against two sets of reference voltages taken either off stack or in a clear stack. The first set is taken in 0% opacity conditions, and the second set is taken in simulated 100% opacity conditions. The resulting reference zero and span voltages produce a reference point by which the transmitter judges current operation.

**d.** **System Considerations.** All procedures in this manual must be performed carefully in order to gain the maximum benefit from the OPM 2000R. Proper maintenance is important for maintaining signal accuracy and will greatly increase instrument life.

**e.** **Dust Concentration Measurements.** The OPM 2000R uses an optical technique to measure opacity and extinction. Equating this to a dust concentration measurement requires additional iso-kinetic sampling in order to calibrate the unit. Iso-kinetic sampling involves taking a series of actual dust concentration measurements in the flue and comparing these with the extinction reading from the OPM 2000R. From this comparison, a graph can be plotted (Figure 1-5) that shows the relationship between extinction and dust measurement exclusive to that particular application. This method takes into account the variation in dust sizes and densities in different applications. The procedure is described in the following standards:

1. ISO 9096 Stationary Source Emissions. Determination of mass concentration and mass flow rate of particulate matter in gas-carrying ducts - manual gravimetric method.

2. ISO/DIS 10155 Stationary Source Emissions. Automated monitoring of mass concentration of particles - performance characteristics, test methods, and specifications.

**1-3.** **METHOD OF MEASUREMENT**. The following sequence of steps determines the relationship of dust concentration to extinction readings:

**a.** After the OPM 2000R has been installed and is functioning properly, a series of gravimetric measurements are taken using a standard method as outlined in ISO 9096. As each measurement is taken, the equivalent extinction reading on the OPM 2000R is recorded.

**b.** The recorded data is plotted and presented in accordance with methods outlined in ISO 10155 or a relevant local standard. This information is used to calculate the "extinction coefficient" that determines the relationship between extinction and dust concentration measurement.

**c.** A typical graph and dust concentration calculation (Figure 1-5) shows a linear relationship between extinction and dust concentration. The calibration curve can be linearized and represented by the following equation:

$$DC = kE + c$$

Where:
- DC = dust concentration
- k = slope of dust concentration by extinction (determined from stack dust sampling test data)
- c = y intercept of dust concentration (determined from stack dust sampling test data)
- E = Extinction (measured variable by OPM 2000R)

The values for k and c are then entered in the DUST SETUP sub-menu of the HART Communicator to calculate the dust concentration (DC) from the extinction value. Refer to paragraph 6-9.e for more information.

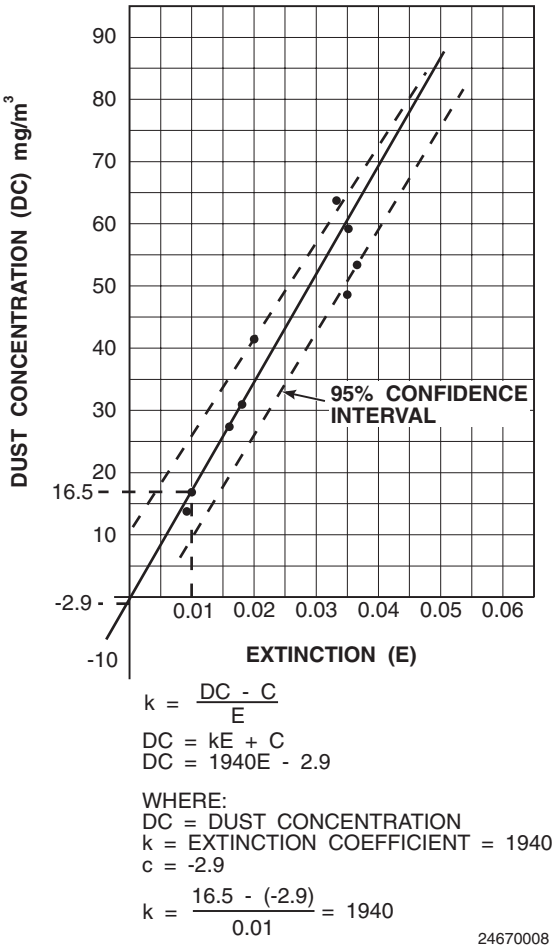



**Figure 1-5. Example Relationship of Extinction and Dust Concentration**

## 1-4. SPECIFICATIONS.

| | |
|---|---|
| **Electrical:** | |
| Input Voltage Requirements | 100/115/220/240 VAC, 50/60 Hz |
| Power Requirements | 400 watts to transceiver, including 300 watt heater. The blowers are separately powered and rated at 1/2 HP @ 60 Hz or 1/3 HP @ 50 Hz (5.6 A @ 115 VAC or 3.1 A @ 240 VAC, 50 Hz). |
| Wiring | Two twisted pair (Belden 8162, 8163, or equivalent); maximum 5000 ft (1524 m) of cable between transceiver and intelligent electronics |
| Electrical Classification | Category II |
| **Environmental:** | |
| Ambient Operating Temperature | -40° to 130°F (-40° to 55°C) |
| Flue Gas Temperature | Maximum 1000°F (538°C); Minimum 220°F (104°C); Non-condensing |
| Flue Gas Pressure | Maximum 10 in. (254 mm) WC with supplied blowers |
| Pathlength | User-definable from 3 to 26 ft (0.9 to 7.9 m) |
| **Physical:** | |
| Optical System | Double-pass multiple lens optical system with solid state electronic light modulation; utilizes liquid crystal windows |
| Light Source | Gas-filled incandescent bulb; expected life greater than 30,000 hours |
| System Shipping Weight | 356 lbs (161.5 kg) |
| **Transceiver and Retroreflector:** | |
| Enclosure Type | Weather housings are moisture-proof. The transceiver assembly is designed for Type 4X environments. |
| Dimensions | Height: 28.77 in. (731 mm)<br>Width: 12.5 in. (318 mm)<br>Depth: 33.94 in. (862 mm) |
| Weight | Transceiver: 80 lbs (36.3 kg)<br>Retroreflector: 40 lbs (18.1 kg) |
| Optical Alignment Sight | Visual alignment sighting indicator utilizing crosshairs |
| **Air Lens Assembly:** | |
| Mounting | Flange mounted to enclosure mounting plate |
| Dimensions | Diameter: 11 in. (280 mm)<br>Length: 6 in. (150 mm)<br>Weight: 18 lbs (8 kg) |
| Blower Motor | Maximum volume 40.0 cfm @ 10 in. $H_2O$ |
| Weight | 29 lbs (13 kg) |
| **Intelligent Electronics:** | |
| Enclosure Type | General Purpose<br>Optional Type 4X |
| Ambient Operating Temperature | 40° to 120°F (4° to 50°C)<br>-40° to 120°F (-40° to 50°C) for optional Type 4X intelligent electronics with heater and thermostat |
| Dimensions | Height: 2.72 in. (69.1 mm)<br>Width: 7.00 in. (177.8 mm)<br>Depth: 5.13 in. (130.3 mm) |
| Weight | 10 lbs (4.54 kg) |
| Voltage | 24 ±1 VDC |
| Power | 25 watts (Optional heater in Type 4X intelligent electronics adds 300 watts.) |
| Contact Rating | 30 VDC, 2 A; 110 VDC, 0.3 A; 125 VAC, 0.5 A |

Operational:

The OPM 2000R meets EPA design and performance requirements as specified in 40 CFR, Part 60, Appendix B, Performance Specification 1. The OPM 2000R also meets the performance audit requirements of EPA Method 203.

| | |
|---|---|
| Output Ranges | Continuously adjustable (field adjustable) |
| Accuracy | ±1% opacity (accuracy of ±1% opacity in normal operating areas, up to 70% opacity reading. Above 70% opacity reading, accuracy of ±2% opacity absolute) |
| Resolution | <0.1% opacity |
| Response Time | <10 seconds |
| Calibration Error | <2% opacity |
| Zero Drift | <2% opacity in 3 months |
| Calibration Drift | <2% opacity in 3 months |
| Spectral Response | 400 to 700 nm (less than 10% outside of this region); 500 to 600 nm peak and mean spectral response |
| Angle of View | <2 degrees |
| Angle of Projection | <2 degrees |
| Zero Check | Automatic verification |
| Span Check | Automatic verification |
| Calibration Filter Access | Provided for EPA verification |
| Measurement Units | Opacity, transmittance, optical density, extinction, and dust concentration |
| Signal Averaging | 13 selectable averages: 0.25, 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60 minutes |
| Automatic Lamp Compensation | Included |
| Automatic Calibration Verification | User-selectable, 1 to 1440 minutes |
| Digital Input | Contact input for remote initiation of zero/span check |
| Analog Outputs | Three linear isolated outputs 4-20 mA; 900 ohms maximum (user-definable) |
| Contact Outputs | Six SPST relays, including two selectable alarms |
| Digital Communications Link | Communications link between transceiver and intelligent electronics processor, 78 k baud |
| Selectable Parameters | Measurement units<br>Signal averaging<br>Optical Path Length Ration (OPLR)<br>Analog output signal selection<br>Alarm settings<br>Manual calibration<br>Computer-assisted EPA filter check |
| Certification | Supplied with Manufacturers EPA Certificate of Compliance (option) |
| Vibration/Expansion Cross Hair Criteria | Within circle of 2% opacity |
| Vibration Frequency | <60 cps |
| Vibration Frequency Magnitude | <0.0025 in. at 60 Hz |

**1-5. SYSTEM STARTUP PROCEDURE.** Use the following steps to start the OPM 2000R. If the opacity transmitter is installed to meet the requirements of EPA regulation 40 CFR, Part 60, Appendix B, Specification 1, follow this procedure prior to installing the opacity transmitter on the stack (see 40 CFR, Part 60, Appendix B, Specification 1, Section 7, PERFORMANCE SPECIFICATION VERIFICATION PROCEDURE). It is also recommended that certain parts of these startup procedures be repeated once the unit is mounted on the stack or duct.

**a.** Turn on power to the transceiver and retroreflector modules immediately after their installation to the stack or duct. Refer to Section IV for the complete installation procedure. Turn on the purge air blowers to ensure that both the transceiver window and retroreflector corner cube will be kept dirt free.

**b.** Turn on the power source to the intelligent electronics and connect the HART Communicator per paragraph 6-2. Turn on the HART Communicator and select CHECK OPTICS from the DIAG/SERVICE menu. Next, select the $V_{STACK}$ menu option to place the OPM 2000R in the check optics mode.

**c.** Align the transceiver and retroreflector. (Refer to Section V for the complete procedure.) If the alignment is performed off of the stack prior to the installation to meet the "prior to installation" requirements of 40 CFR, Part 60, Appendix B, Specification 1, be sure the transceiver and retroreflector modules are spaced within 1/4 in. (6.35 mm) of the actual installed flange-to-flange distance. Exit the CHECK OPTICS procedure when alignment is complete.

**d.** Set up the operating parameters in the BASIC SETUP and DETAILED SETUP menus of the HART Communicator. Refer to paragraphs 6-8 and 6-9 for the complete setup procedures.

**e.** Enter the PROCESS VARIABLES menu and select FLD DEVICE VOLTS per paragraph 6-6.a. Four voltages are listed: $V_{STACK}$ (stack), $V_{LAMP}$ (lamp), $V_{AMB}$ (ambient), and $V_{DARK}$ (dark). Selecting STACK TEMPERATURE displays VAD590 (ambient voltage) and TEMP (transceiver electronics temperature). These voltages and temperature readings indicate the up-to-date levels of these measured variables. If the stack or duct is clear of opacity, the stack and lamp voltages will be within 0.5 volts of each other. The typical values for both stack and lamp volts as set by the factory are 4.0 V.

**NOTE**

**The actual ambient conditions at the installation site may not be the same as the factory conditions at the time of testing. Therefore, some variations in these two voltages will be observed but will not affect the operation of the opacity transmitter.**

**f.** View the opacity reading on the HART Communicator display online menu. Ensure the primary variable (PV) or the secondary variable (SV) is set to display opacity. Refer to paragraph 6-6.b. Under clear stack conditions, or with zero jig installed, the opacity should now read 0.0%. If the opacity reading is other than 0.0 ±0.5%, recalibrate the opacity transmitter.

**g.** Perform an offline calibration per paragraph 6-7.b. Reference voltages from the last offline calibration are stored in the REF. VOLTAGES sub-menu in the DIAG/SERVICE menu. This stored data should be recorded and saved for later reference before proceeding with another offline calibration.

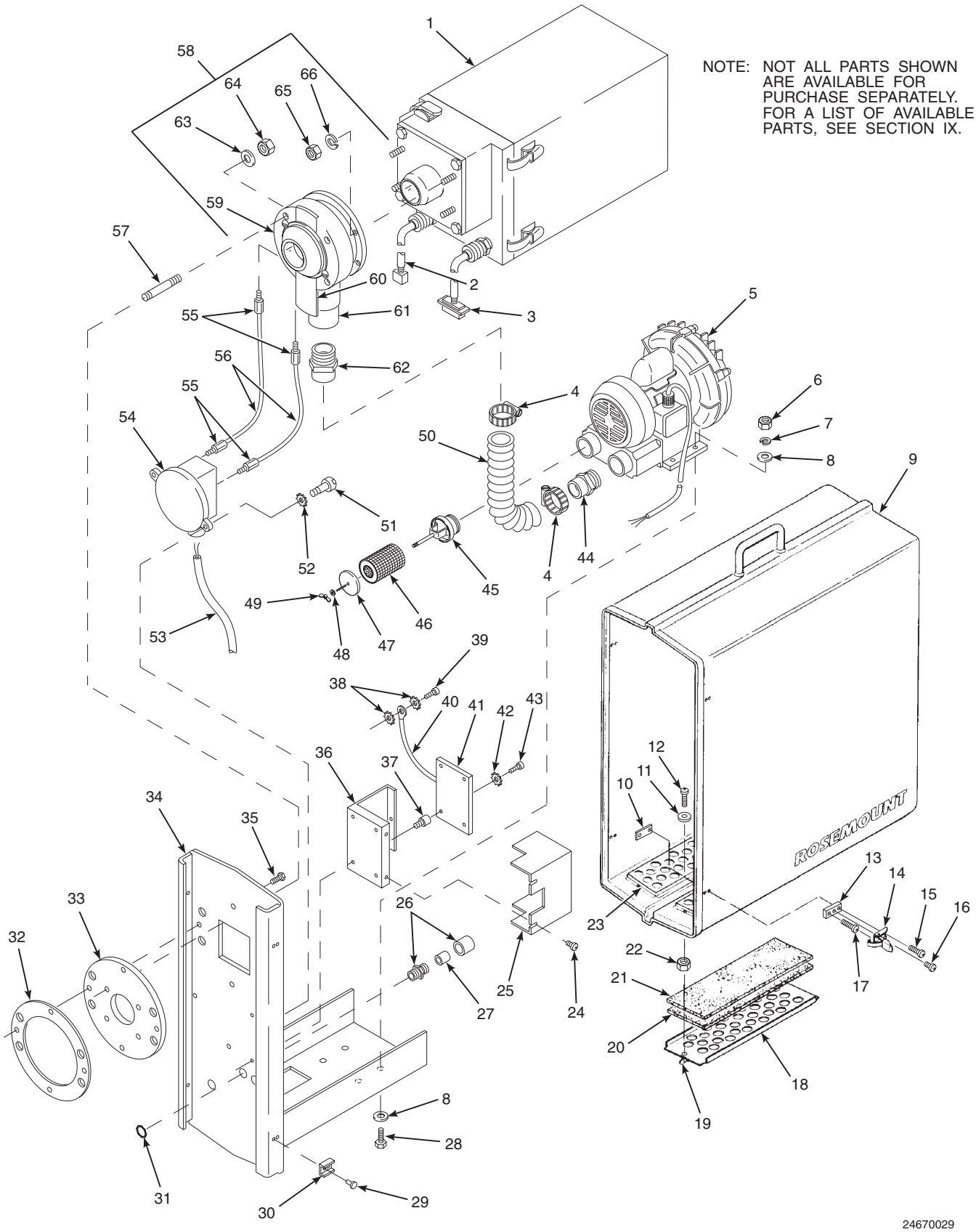



**Figure 2-1. Transceiver Module - Exploded View**

# SECTION II. TRANSCEIVER AND RETROREFLECTOR MODULES

**2-1.** **TRANSCEIVER MODULE.** The main components of the transceiver module (Figure 2-1) are optical assembly (1, Figure 2-1 and Figure 2-2), air lens (58, Figure 2-1), and blower motor (5). The three components are mounted to mounting plate (34) and enclosed in weather housing (9). The optical assembly contains all transceiver optical and electronic components. Lifting and handling instructions for the transceiver and the retroreflector can be found in paragraph 4-5.

**a.** **Optical System.** The light source for the optical system is a special, long-life incandescent lamp. The lamp contains a built-in lens that directs light forward through a 1/8 in. (3 mm) diameter crosshaired aperture. Two Liquid Crystal Windows (LCWs) function as shutters that either block or transmit light. The LCWs are made of a normally translucent film that scatters the light striking it. However, when an electric current is applied to the film, the LCW becomes transparent and allows light to pass. The sequence in which the LCWs turn on or off and the duration of each are software-controlled.

**LEGEND FOR FIGURE 2-1**

| ITEM | DESCRIPTION | ITEM | DESCRIPTION | ITEM | DESCRIPTION |
|---|---|---|---|---|---|
| 1 | Optical Assembly | 24 | Pan Head Screw, #8-32 x 3/8 in. | 47 | Filter Cover |
| 2 | Power Cable | 25 | Top Cover Plate | 48 | Flat Washer, 3/8 in. |
| 3 | Communications Cable | 26 | Cable Grip | 49 | Wing Nut, 3/8-16 |
| 4 | Hose Clamp | 27 | Seal | 50 | Hose |
| 5 | Blower Motor | 28 | Bolt, 1/4-20 x 1-1/4 in. | 51 | Screw, #10-32 x 3/8 in. |
| 6 | Hex Nut, 1/4-20 | 29 | Rivet | 52 | External Star Washer, #10 |
| 7 | Lockwasher, 1/4 in. | 30 | Latch | 53 | Purge Air Failure Flow Switch Cable |
| 8 | Washer, 1/4 in. | 31 | Conduit Lock Nut, 1/2 in. | 54 | Purge Air Failure Flow Switch |
| 9 | Weather Housing | 32 | Gasket | 55 | Straight Connector |
| 10 | Mounting Plate | 33 | Flange | 56 | Air Tubing |
| 11 | Washer, 1/4 in. | 34 | Mounting Plate | 57 | Stud |
| 12 | Pan Head Screw, 1/4-20 x 7/8 in. | 35 | Bolt, 1/4-20 x 5/8 in. | 58 | Air Lens Assembly (Includes items 59 through 62) |
| 13 | Mounting Block | 36 | Bottom Cover Plate | 59 | Ball Seat |
| 14 | Toggle Clamp | 37 | Standoff, #6-32 x 1/2 in. | 60 | Seal Plate |
| 15 | Pan Head Screw, #8-32 x 3/4 in. | 38 | External Star Washer, #6 | 61 | Check Valve |
| 16 | Pan Head Screw, #8-32 x 3/8 in. | 39 | Screw, #6-32 x 1/4 in. | 62 | Adapter |
| 17 | Pan Head Screw, #8-32 x 7/8 in. | 40 | Ground Cable | 63 | Spherical Washer, 3/8 in. |
| 18 | Filter Retainer | 41 | Termination Board | 64 | Spherical Hex Nut, 3/8-16 |
| 19 | Wing Nut, 1/4-20 | 42 | External Star Washer, #6 | 65 | Hex Nut, 5/16-18 |
| 20 | Filter (Coarse) | 43 | Screw, #6-32 x 1/4 in. | 66 | Lockwasher, 5/16 |
| 21 | Filter (Fine) | 44 | Adapter | | |
| 22 | Nut, 1/4-20 | 45 | Filter Base | | |
| 23 | Filter Retainer | 46 | Filter Element Assembly | | |

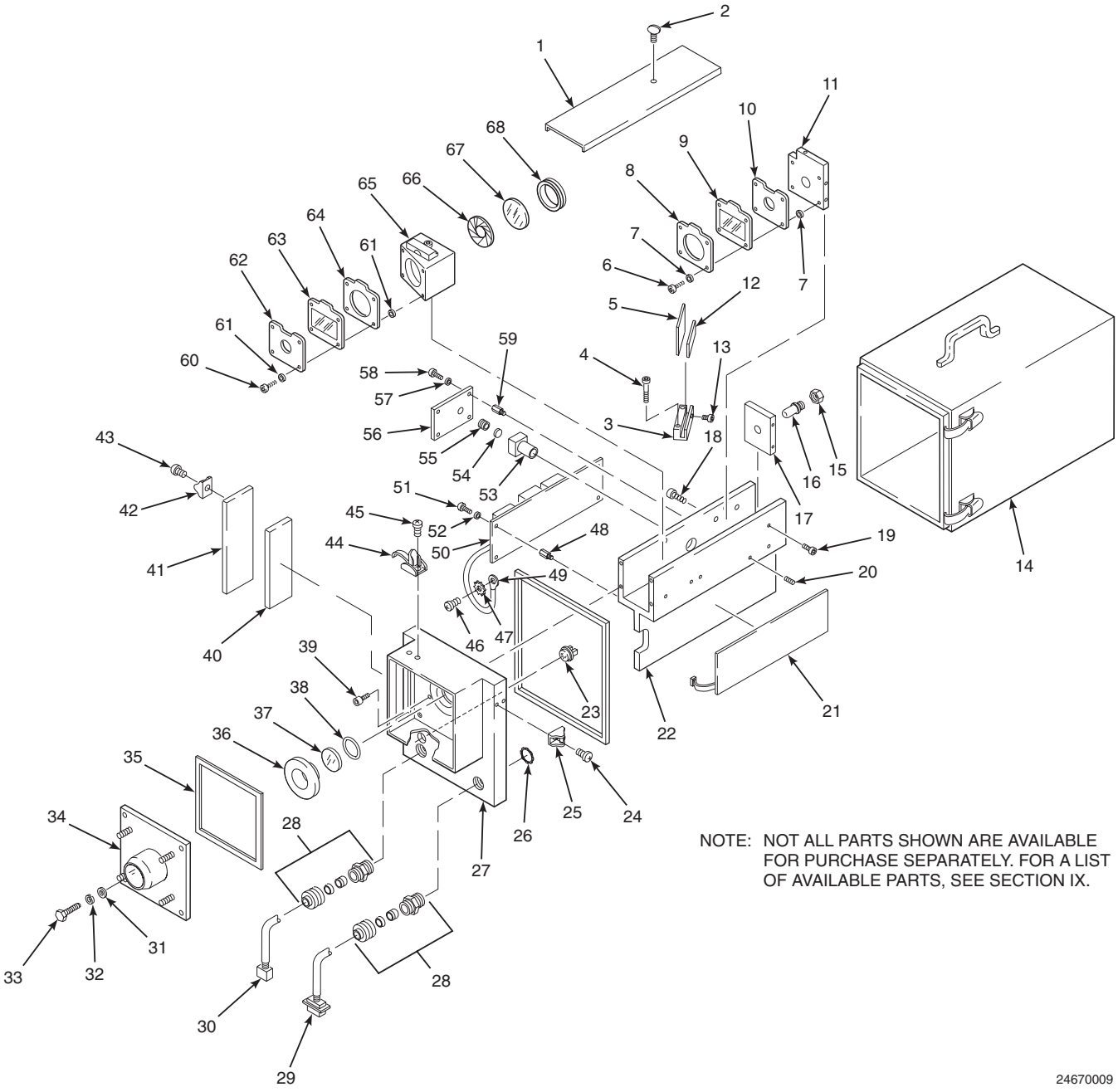



**Figure 2-2. Transceiver Optical Assembly - Exploded View**

**LEGEND FOR FIGURE 2-2**

| ITEM | DESCRIPTION | ITEM | DESCRIPTION | ITEM | DESCRIPTION |
|---|---|---|---|---|---|
| 1 | Cover Plate | 22 | Optical Mounting Channel | 46 | Pan Head Screw, #6-32 x 3/8 in. |
| 2 | Thumbscrew, #6-32 x 3/8 in. | 23 | CAL/CHECK Backlit Pushbutton | 47 | External Star Washer, #6 |
| 3 | Splitter Base | 24 | Pan Head Screw, #8-32 x 1/4 in. | 48 | Standoff, #6-32 x 1/2 in. |
| 4 | Socket Head Screw, #6-32 x 1 in. | 25 | Latch Clip | 49 | Ground Cable |
| 5 | Beam Splitter | 26 | Conduit Lock Nut, 1/2 in. | 50 | Stack LON Board |
| 6 | Socket Head Screw, #4-40 x 1/2 in. | 27 | Mounting Plate | 51 | Socket Head Screw, #6-32 x 3/8 in. |
| 7 | O-Ring | 28 | Cable Grip | 52 | Internal Star Washer, #6 |
| 8 | Aperture | 29 | Communication Cable | 53 | Detector Mount |
| 9 | LCW 1 | 30 | Power Cable | 54 | Green Filter |
| 10 | Aperture | 31 | Flat Washer, 1/4 in. | 55 | Detector |
| 11 | Mounting Block | 32 | Lockwasher, 1/4 in. | 56 | Detector/Amplifier Board |
| 12 | Retainer | 33 | Hex Head Bolt, 1/4-20 x 1 in. | 57 | Internal Star Washer, #6 |
| 13 | Socket Head Screw, #6-32 x 3/8 in. | 34 | Window Flange | 58 | Socket Head Screw, #6-32 x 3/8 in. |
| 14 | Electronics Housing | 35 | Gasket | 59 | Standoff, #6-32 x 1/2 in. |
| 15 | Stop Nut | 36 | Threaded Retaining Ring | 60 | Socket Head Screw, #4-40 x 1/2 in. |
| 16 | Lamp | 37 | Front Window | 61 | O-Ring |
| 17 | Lamp Holder | 38 | O-Ring | 62 | Reflector |
| 18 | Socket Head Screw, #6-32 x 1/2 in. | 39 | Socket Head Screw, #6-32 x 5/8 in. | 63 | LCW 2 |
| 19 | Socket Head Screw, #6-32 x 1/2 in. | 40 | Gasket | 64 | Aperture |
| 20 | Set Screw, 1/4-20 x 1/4 in. | 41 | Access Plate | 65 | Mounting Block |
| 21 | Heater | 42 | Latch Clip | 66 | Iris |
| | | 43 | Rivet | 67 | Objective Lens |
| | | 44 | Latch | 68 | Lens Retainer |
| | | 45 | Pan Head Screw, #8-32 x 1/4 in. | | |

Each measurement cycle consists of four different light path modes; each mode produces a different voltage. The four measurement modes are stack, ambient, dark, and lamp and are explained as follows:

1. Stack Mode. Refer to Figure 2-3. During the stack mode, the light beam passes through the aperture (with crosshairs), LCW 1, and beam splitter. Then, the beam travels through the objective lens, LCW 2 (center segment), and an air window; across the stack; and into a retroreflector. The retroreflector, by means of a corner cube, reflects the light back through the stack, air window, LCW 2, iris, and objective lens. The beam strikes the beam splitter and is reflected into the detector. The detector (a photodiode) converts the light to a voltage that can be processed. The desired spectral response is achieved by a narrow green band filter on the detector.

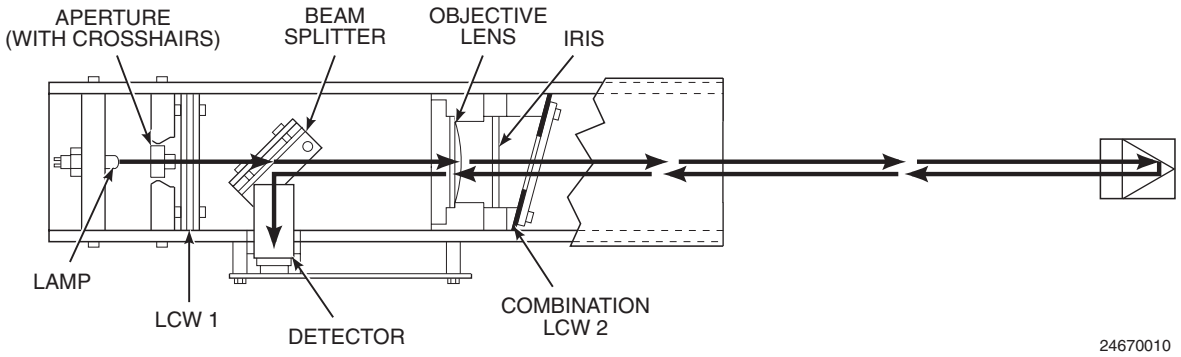



**Figure 2-3. Stack Light Path**

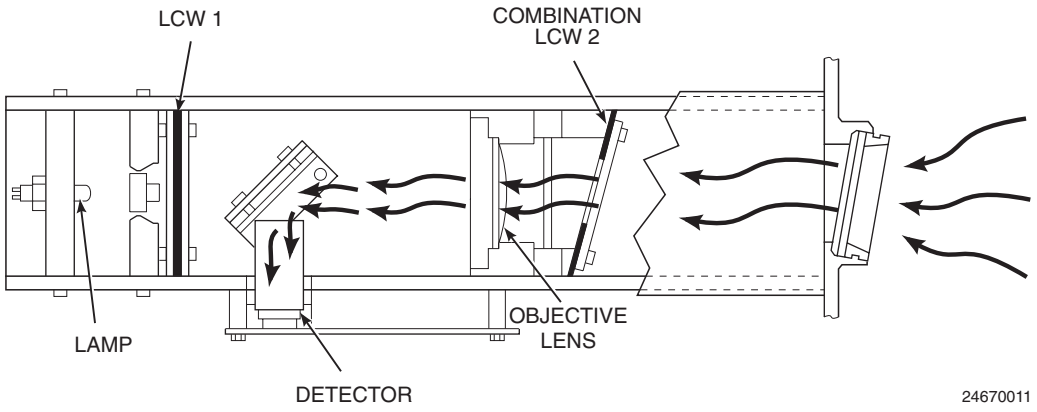



**Figure 2-4. Ambient Light Path**

2. Ambient Mode. Refer to Figure 2-4. In the ambient mode, LCW 1 blocks the lamp's light, preventing it from ever reaching the detector. While the lamp light is blocked, LCW 2 allows ambient light to reach the objective lens, beam splitter, and detector.

3. Dark Mode. Refer to Figure 2-5. In the dark mode, both LCWs are off. The voltage measured during the dark mode is used to compensate for any internal light leakage within the transceiver.

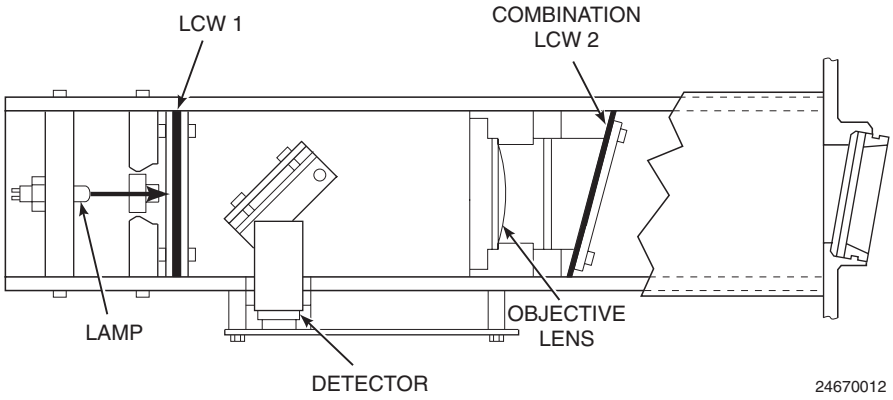



**Figure 2-5. Dark Mode**

4. Lamp Mode. Refer to Figure 2-6. The lamp mode allows the OPM 2000R to compensate for the effects of an aging bulb. In this mode, the inner segment of LCW 2 is off, stopping the beam from reaching the air window and preventing the entrance of ambient light. The lamp beam is directed through the objective lens and the outer ring segments of LCW 2 to an internal retroreflector located behind the outer ring segments. The beam is then directed back through the objective lens to the beam splitter and into the detector. The iris installed over the objective lens can be adjusted to keep the lamp voltage within 1/2 V of the stack voltage.

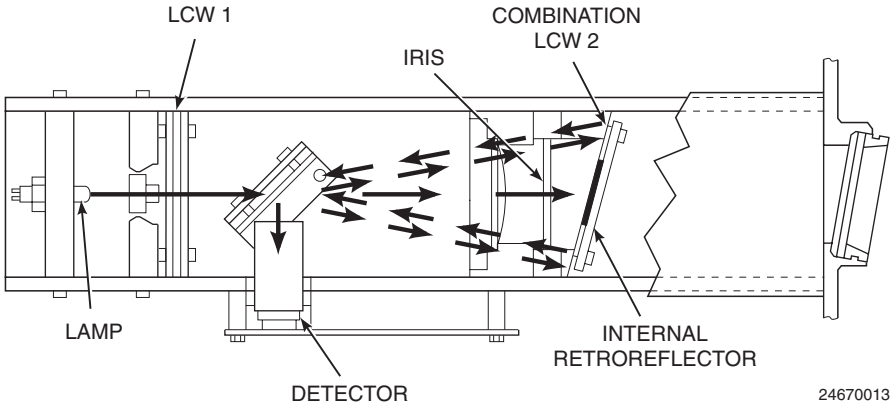



**Figure 2-6. Lamp Light Path**

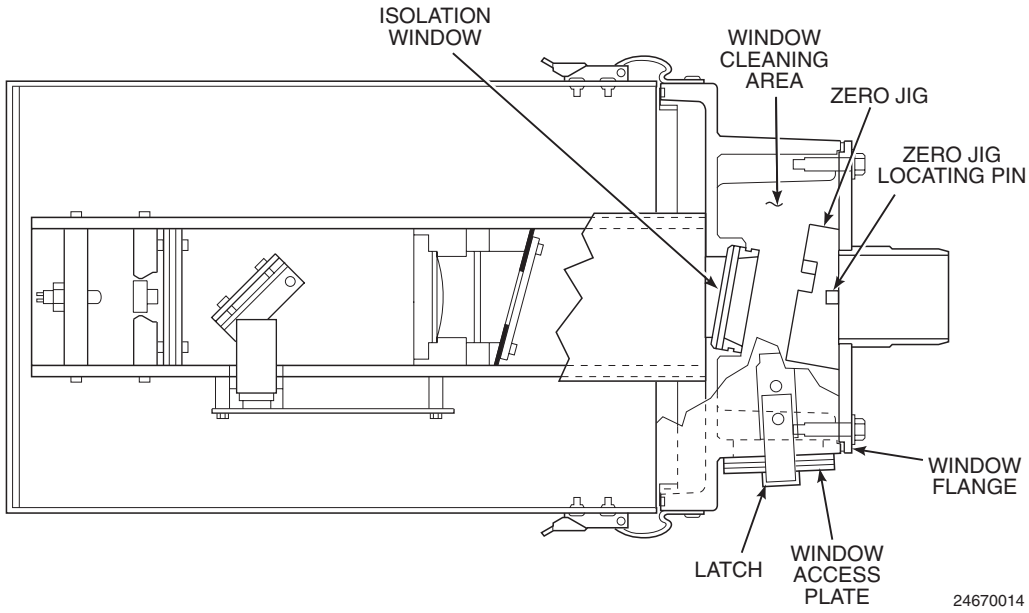



**Figure 2-7. Zero Jig Mounting Location**

**b. <u>Filters and Zero Jig</u>.** An external neutral density filter check is used to meet EPA requirements concerning monitor accuracy and calibration. To check the monitor, remove the window access plate (Figure 2-7) and position the zero jig onto the window flange. Then, insert EPA-certified neutral density filters in the zero jig, one at a time, and compare the filter values with the actual monitor readings. This comparison shows the monitor's accuracy. Refer to paragraph 6-7.g for complete instructions.

**c. <u>Detector/Amplifier PC Board</u>.** The detector is a photodiode that converts light energy to a voltage. A green filter in front of the detector is used to achieve the desired spectral response. The filter's maximum response is at 550 nm (Figure 2-8). At below 400 nm and above 700 nm, the filter transmits less than 2% of the light.

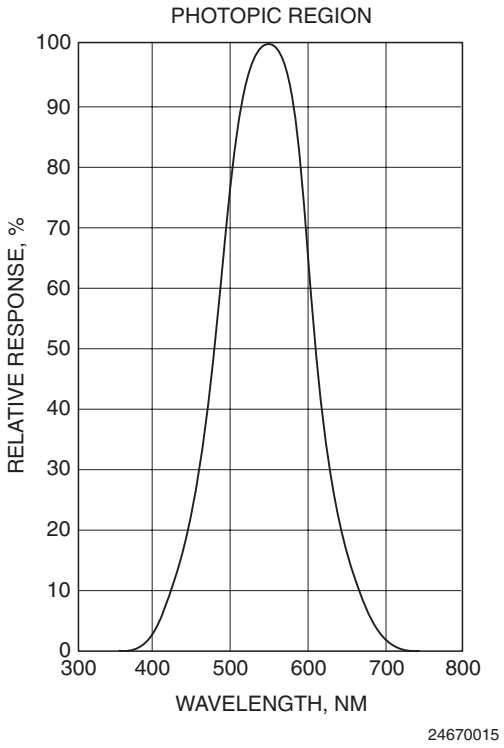



**Figure 2-8. Effective Spectral Response Curve**

Detector CR1 (Figure 2-9) is mounted to the detector/amplifier PC board, which amplifies the signal. The board contains a 2-position jumper to adjust the range of gain. If the jumper is in the low position (JM1), the gain adjustment is from 1 to 10. In the high position (JM2), the gain is from 10 to 100. Potentiometer R1 allows adjustment within the range determined by the jumpers (Figure 2-10).

**d.** **Stack LON Board.** Refer to Figures 2-9 and 2-11. The stack LON board is mounted to the optical mounting channel. The electronics on the stack LON board include the communications electronics, temperature sensor, heater controller, purge air failure flow switch input modules, and DC power supplies. Power supply 1 (PS1) supplies power to the lamp and electronics. Power supply 2 (PS2) supplies power to LCW 1, LCW 2, and a status LED.

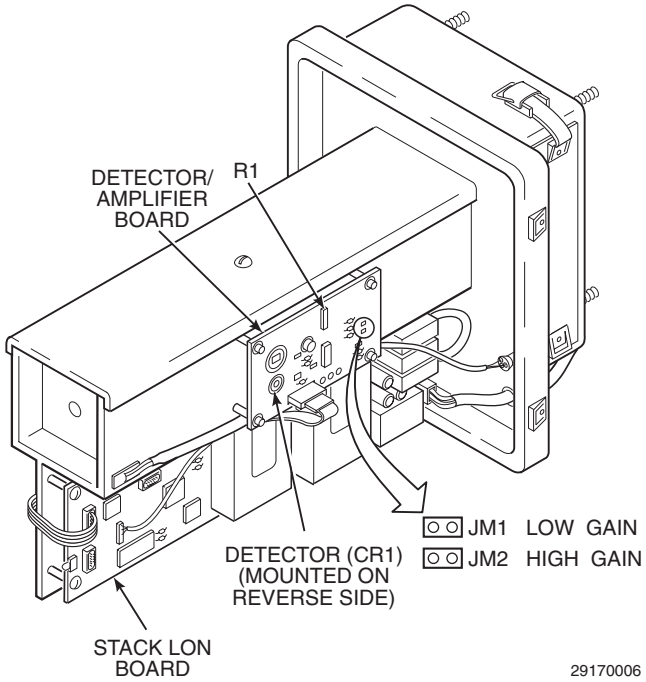
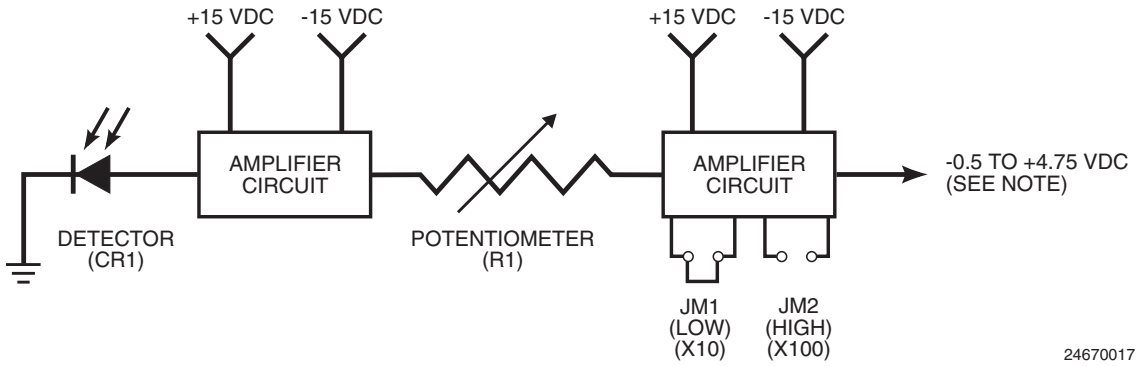



**Figure 2-9. Optical Mounting Channel (with Boards)**

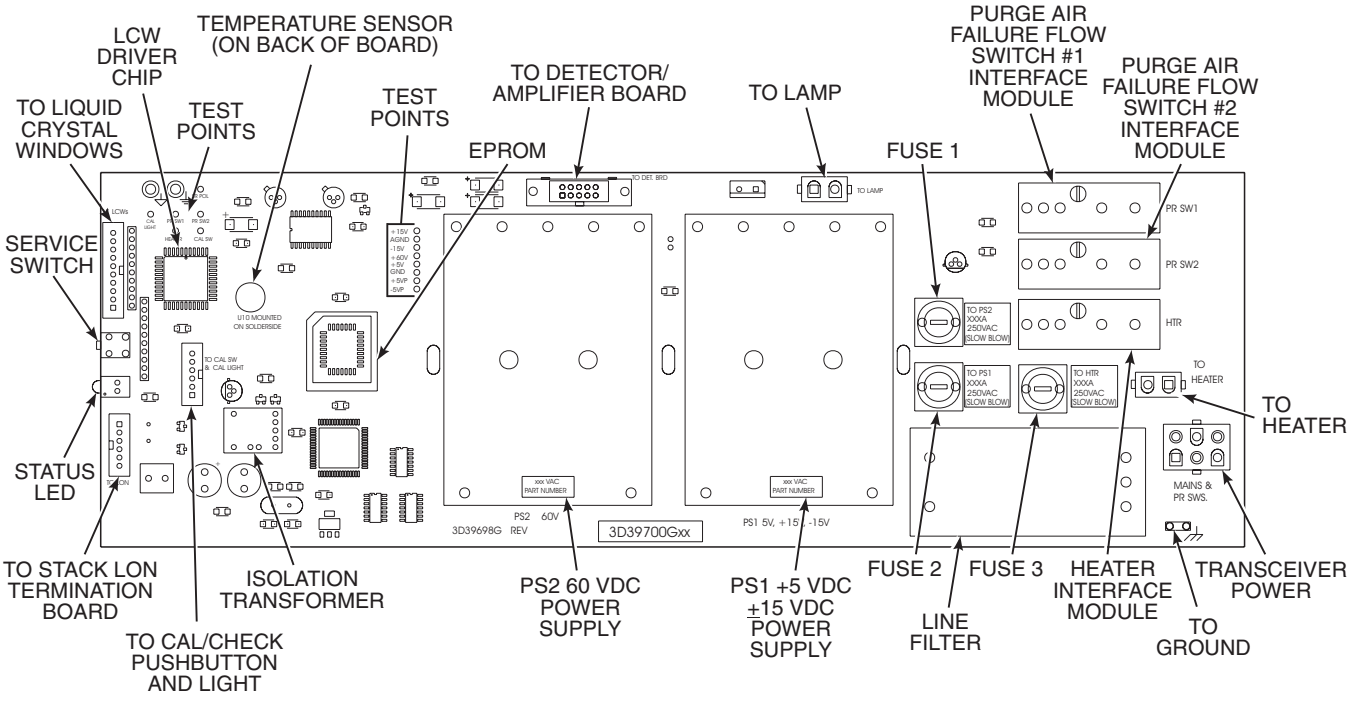



NOTE: -0.5 VDC AND +4.75 VDC ARE DETECTOR AMPLIFIER SATURATION VALUES. TYPICALLY, LAMP AND STACK MODE VOLTAGE READINGS ARE +3.0 VDC TO +4.0 VDC. POTENTIOMETER R1 CAN BE ADJUSTED TO PREVENT AMPLIFIER SATURATION. POTENTIOMETER R1 DOES NOT AFFECT CALIBRATION.

**Figure 2-10. Detector Circuit**

**e. Termination Board.** Termination board (41, Figure 2-1) is installed on mounting plate (34) and provides a connection point for cables to and from the transceiver. The board provides connections for the transceiver and retroreflector purge air failure flow switches, stack LON board power supplies, and AC power input. Refer to Figure 4-9 or 4-10 for an illustration and wiring schematic of the termination board.

**f. Heater.** Allowing the temperature in the optical unit to reach or fall below freezing could result in improper OPM 2000R operation. For this reason, a heater is installed on the optical mounting channel. The temperature circuitry on the stack LON board turns the heater on when the temperature in the transceiver assembly is below 85.1°F (29.5°C) and off when the temperature in the transceiver assembly is above 86°F (30°C).



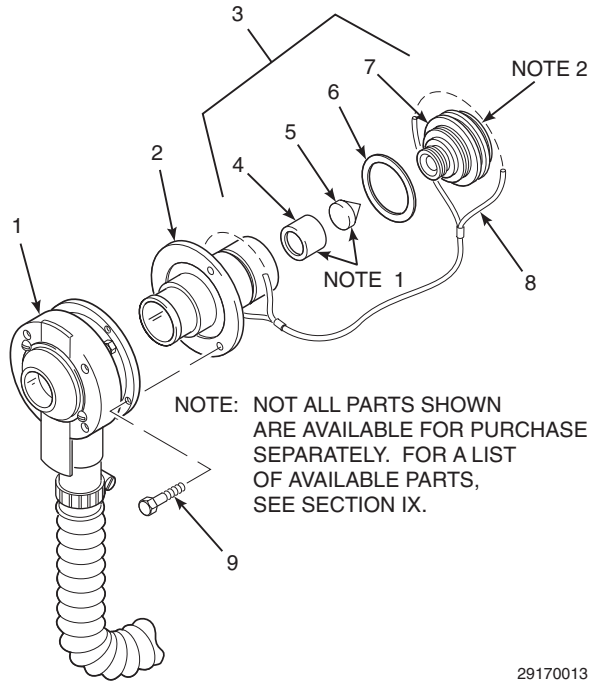

FUSE CHART

| | 100/115 VAC | 220/240 VAC |
|---|---|---|
| 1 | 1A97913H12 | 1A97913H17 |
| 2 | 1A97913H10 | 1A97913H09 |
| 3 | 1A97913H03 | 1A97913H16 |

24670018

**Figure 2-11. Stack LON Board**

**2-2. RETROREFLECTOR MODULE.** The retroreflector module is similar to the transceiver module. However, instead of an optical assembly (1, Figure 2-1), the retroreflector module has a corner cube reflector mounted to the air lens assembly (Figure 2-12).




NOTE 1: DIFFERENT CORNER CUBES AND HOLDERS ARE USED AS FOLLOWS:

| PATHLENGTH | CORNER CUBE |
|---|---|
| 3 to 10 ft (0.915 to 3.05 m) | 0.5 in. (12.7 mm) Diameter Corner Cube |
| 10 to 20 ft (3.05 to 6.1 m) | 1 in. (25.4 mm) Diameter Corner Cube |
| 20 to 26 ft (6.1 to 7.9 m) | 1.5 in. (38.1 mm) Diameter Corner Cube |

NOTE 2: THE FLAT SURFACE SIDE OF THE END CAP IS A "ZERO-REFLECTOR" AND CAN BE USED TO SIMULATE 100% OPACITY.

| ITEM | DESCRIPTION |
|---|---|
| 1 | Air Window |
| 2 | Retroreflector Body |
| 3 | End Cap and Corner Cube Assembly |
| 4 | Corner Cube Holder |
| 5 | Corner Cube (Retroreflector) |
| 6 | Gasket |
| 7 | End Cap (Zero Reflector) |
| 8 | Retaining Strap |
| 9 | Screws (3) |

**Figure 2-12. Retroreflector and Air Lens Assembly**

The retroreflector consists of retroreflector body (2, Figure 2-12) and end cap and corner cube assembly (3). The latter consists of corner cube holder (4), corner cube (5), gasket (6), and end cap (zero reflector) (7). Light from the transceiver passes through the stack and into the retroreflector. The corner cube reflects the beam back along the same path. Refer to Section V for more information on checking and aligning the transceiver and retroreflector modules.

During calibration, it is possible to simulate 100% opacity by removing the end cap and corner cube assembly. Upon removal, reverse the end cap and reinstall with the flat (zero reflector) side facing the retroreflector body.

**2-3. PURGE AIR FAILURE FLOW SWITCH.** The OPM 2000R contains two purge air failure flow switches (Figure 2-13). One switch is mounted on the transceiver module mounting plate; the other is mounted on the retroreflector module mounting plate. Each switch continuously monitors the differential pressure across its respective air lens assembly. If the differential pressure falls below a preset value, the

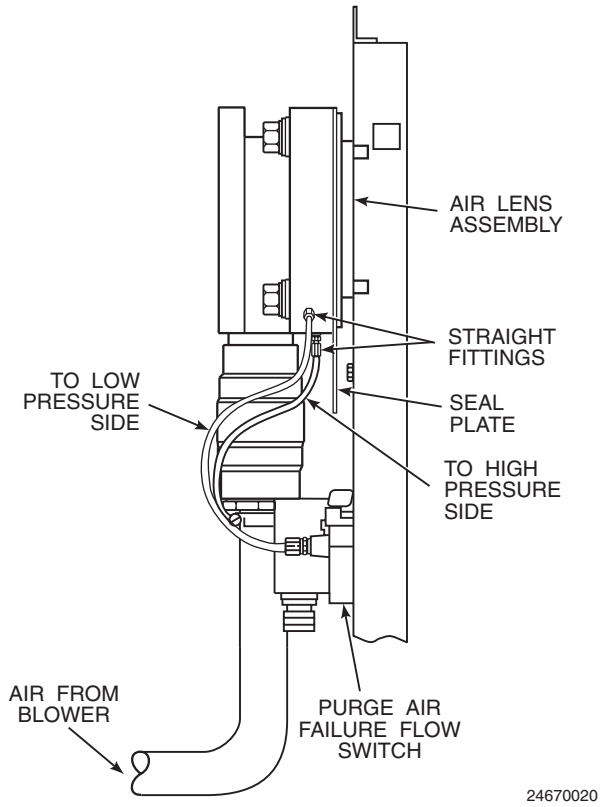
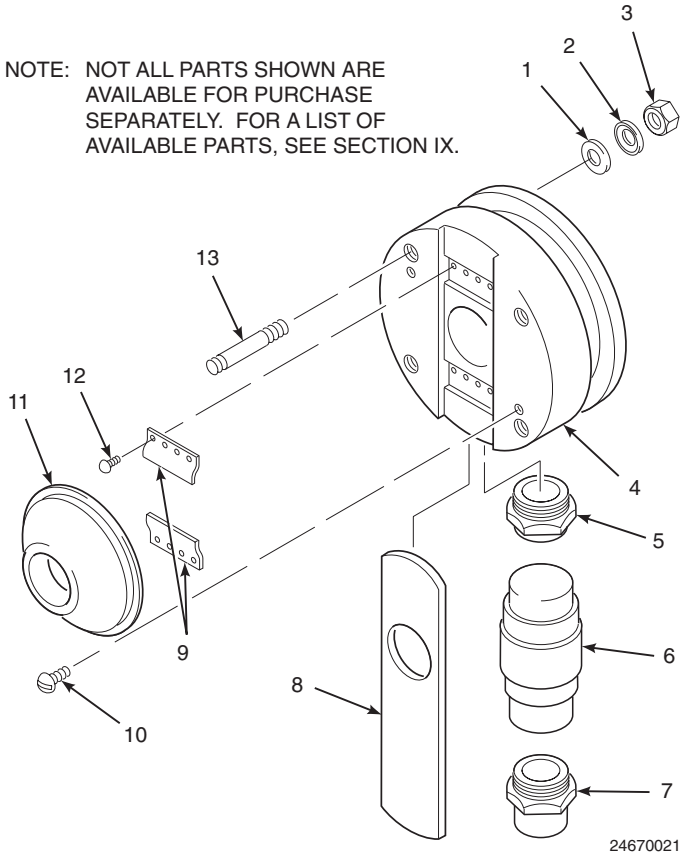



**Figure 2-13. Air Lens Assembly and Purge Air Failure Flow Switch**

affected switch opens. The purge air failure flow switch interface module sends an alarm signal through the stack LON board to the intelligent electronics. The intelligent electronics distinguishes which unit has failed (transceiver or retroreflector) and displays the flow switch status using a HART Communicator.

**2-4. AIR LENS ASSEMBLY.** An air lens assembly (Figure 2-14) is mounted to the mounting plate inside the weather housing of both the transceiver and retroreflector modules. Each air lens, by receiving purge air from its own blower, is capable of maintaining a clean space of air between the module's optics and the stack gases and particulates. A manually positioned sliding seal plate is used to protect the instrument from flue gases and particulates when the blower is off. Ball-joint construction of the assembly provides for horizontal and vertical alignment adjustments. Refer to paragraph 5-1.

Coarse and fine filters (20 and 21, Figure 2-1) are located at the bottom of the weather housings. The filters remove airborne particulates as air is drawn through the filters by the suction of the blower. Secondary filter element (46) mounts directly to the blower intake. The filters can be easily removed for cleaning and reuse. Refer to paragraph 8-2.d.




| ITEM | DESCRIPTION |
|---|---|
| 1 | Convex Washers (4) |
| 2 | Concave Washers (4) |
| 3 | Adjusting Nuts (4) |
| 4 | Housing |
| 5 | Upper Adapter |
| 6 | Check Valve |
| 7 | Lower Adapter |
| 8 | Seal Plate |
| 9 | Seal Springs |
| 10 | Ball Plate Screws (2) |
| 11 | Ball Plate |
| 12 | Screw |
| 13 | Stud (4) |

**Figure 2-14. Air Lens Assembly - Exploded View**

# SECTION III. INTELLIGENT ELECTRONICS

**3-1.** **GENERAL.** The intelligent electronics is the control unit of the OPM 2000R. It continuously receives digital signals from the transceiver via the communications link and converts them into readings of opacity, transmittance, optical density, extinction, and dust density. In addition, the intelligent electronics sends commands to the transceiver to initiate diagnostic tests and provides an operator interface via HART communications.

Two types of intelligent electronics are available: the standard general purpose version for indoor use and the optional Type 4X weatherproof version for outdoor use.

**3-2.** **INTELLIGENT ELECTRONICS (GENERAL PURPOSE).** The general purpose intelligent electronics unit (Figure 3-1) consists of two boards: the IG-1 software board (6) and the HART daughter board (15).

**a.** **IG-1 Software Board.** The IG-1 software board (6, Figure 3-1 and Figure 3-2) contains the software program, three LED indicators, and connections to the transceiver, power source, and HART daughter board (15, Figure 3-1).

| ITEM | DESCRIPTION | ITEM | DESCRIPTION |
|---|---|---|---|
| 1 | 4-Pin Plug | 9 | 6-Pin Plug |
| 2 | 3-Pin Plug | 10 | 9-Pin Plug |
| 3 | Screw, M3 x 6 | 11 | Grommet |
| 4 | Endplate | 12 | Standoff, #4-40 x 15/16 in. |
| 5 | Enclosure | 13 | External Star Lockwasher, #4-40 |
| 6 | IG-1 Software Board | 14 | Screw, #4-40 x 1/4 in. |
| 7 | Lock Nut, #4-40 | 15 | HART Daughter Board |
| 8 | Endplate | | |

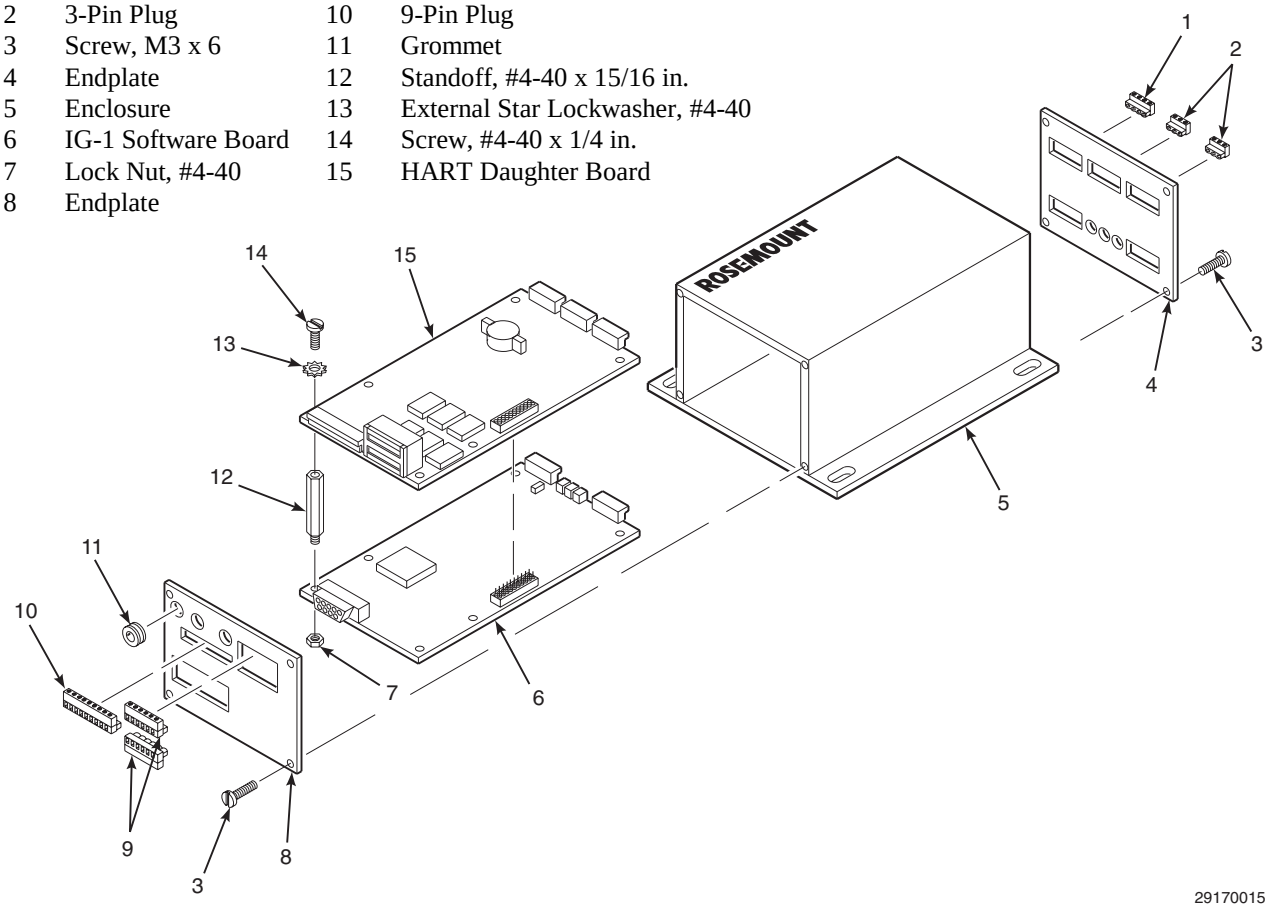



**Figure 3-1. General Purpose Intelligent Electronics - Exploded View**

1. IG-1 Software. The software program that controls the intelligent electronics resides in PROM U4 (Figure 3-2). To check the version level of your software, access the REVIEW menu using the HART Communicator. Refer to Section VI for more information. It is only necessary to replace the PROM for a software upgrade. The factory will determine if the software change is mandatory for units already shipped. If you require a replacement board, the new board will contain the latest software revision.

2. LEDs. Three LEDs are mounted to the side of the software board: FAULT, COMM, and POWER.

   (a) The yellow FAULT LED turns on when a fault occurs on the IG-1 software board.

   (b) The COMM LED indicates when data is transferring between the transceiver and the intelligent electronics. A green light indicates the intelligent electronics is receiving information. A red light indicates the intelligent electronics is sending information.

   (c) The green POWER LED lights when the power source to the intelligent electronics is turned on.

3. LON Connection. The wiring that attaches to the LON connector provides the communication link between the intelligent electronics and the transceiver.

4. +24 V Connection. The +24 V connector is wired directly to the HART daughter board.

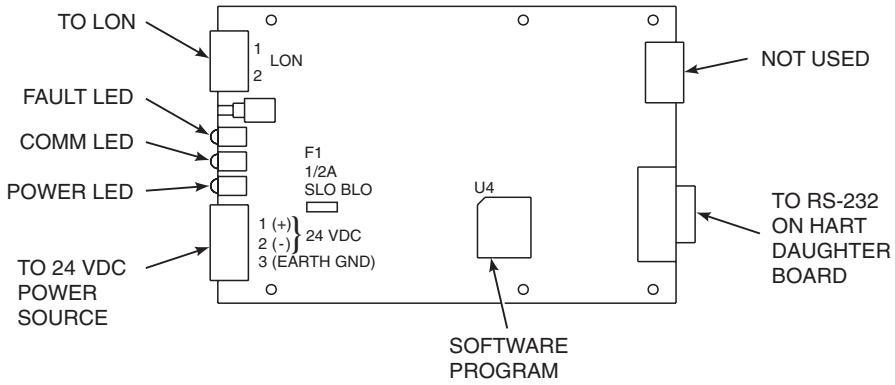
5. RS-232 Connector. The 9-pin connector establishes a communication link between the HART daughter board and the software board.

6. F1 Fuse. This Pico II, 1/2 amp, Slo Blo fuse provides board circuit protection from the incoming power source.

**b. HART Daughter Board.** The HART daughter board (15, Figure 3-1 and Figure 3-3) contains the real-time clock, relay jumper blocks, and connections to the transceiver, power source, HART Communicator, analog outputs, relay contacts, and digital input.

1. Clock. The HART daughter board contains a real-time clock that receives power from an on-board rechargeable lithium battery during power outages and when the board is removed from the intelligent electronics.

2. 4-20 mA LOOP TO STACK Connection (J2). The wiring that attaches to the 4-20 mA LOOP TO STACK connector establishes a 4-20 mA signal loop between the intelligent electronics and the transceiver. The HART Communicator only operates on the 4-20 mA signal loop. By running the signal loop between the intelligent electronics and the transceiver, you can use the HART Communicator to interface with the OPM 2000R at either the intelligent electronics or transceiver installation site.




NOTE: IN A NEMA 4X INTELLIGENT ELECTRONICS, THE 24 VDC CONNECTOR CONNECTS TO A UNIVERSAL POWER SUPPLY THAT CONVERTS THE INCOMING LINE VOLTAGE TO 24 VDC.

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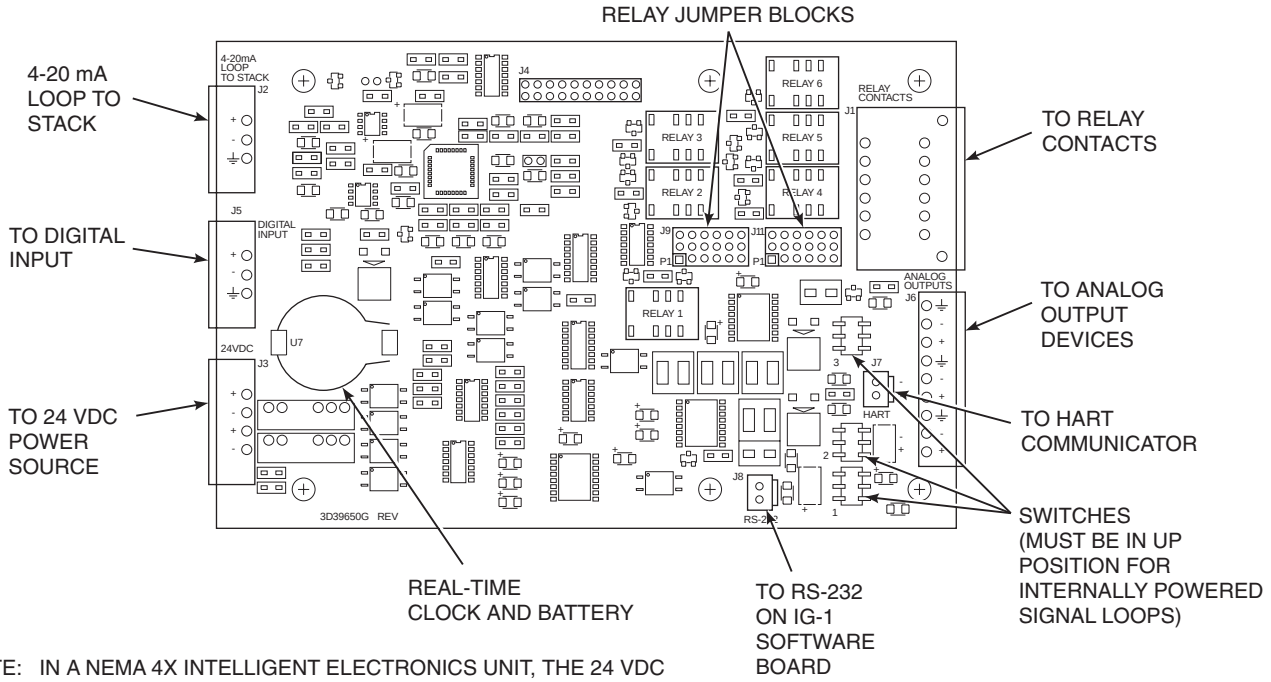
**Figure 3-2. IG-1 Software Board**




NOTE: IN A NEMA 4X INTELLIGENT ELECTRONICS UNIT, THE 24 VDC CONNECTOR CONNECTS TO A UNIVERSAL POWER SUPPLY THAT CONVERTS THE INCOMING LINE VOLTAGE TO 24 VDC.

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**Figure 3-3. HART Daughter Board**

3. 24 VDC Connection (J3). The 24 VDC connector is wired directly to the 24 VDC power source. Rosemount offers an optional 115 VAC or 220 VAC/24 VDC power supply that will transform the voltage to the 24 VDC needed.

4. Digital Input (J5). The digital input connector gives you the opportunity to initiate a zero/span check via a remote input such as a computer control system. This is in addition to the scheduled zero/span check configured with the HART Communicator. The contact input is interrogated by the intelligent electronics with 5 VDC.

5. Relay Contact Connection (J1). The relay contact connector can be wired to external devices that utilize OPM 2000R status indications. The six relays are configured using the HART Communicator. Refer to paragraph 6-9.a for more information.

6. Analog Output Connection (J6). The analog output connector can be wired to a recorder, controller, or computer that utilizes isolated analog readings from the OPM 2000R. The three analog outputs are determined by the PV, SV, and TV values configured using the HART Communicator. Analog output 1 (AO1), which always has the PV value, also carries the digital HART communications signal. Refer to paragraph 6-6.d for more information.

7. HART Connection (J7). The intelligent electronics provides two banana jack receptacle cable assemblies to plug the HART Communicator into the 4-20 mA signal loop. The cable assemblies are located on the endplate of the intelligent electronics, and their terminals plug into HART connector J7 on the HART daughter board. Refer to paragraph 6-2 for more information on attaching the HART Communicator to the signal loop.

8. Switches 1, 2, and 3. These switches can be configured in the up position to power the analog outputf circuit by the OPM 2000R or in the down position to power the analog output circuit by the field device receiving the analog output signal from the OPM 2000R.

9. Relay Jumper Blocks (J9 and J11). The relays on the HART daughter board are now configurable via two jumper blocks: J9 and J11 (Figure 3-4). This new feature was added to provide additional flexibility when configuring the instrument's alarm outputs. J9 can be configured so the instrument's relay contacts are either normally energized or normally de-energized during normal operating conditions. J11 can be configured so the contacts are either normally open or closed during normal operating conditions. These terms are explained below:

   **Normally Open Relay —** A relay with open contacts when it is in an unpowered state.

   **Normally Closed Relay —** A relay with closed contacts when it is in an unpowered state.

   **Normally Energized Relay —** A relay with its coil energized during normal operating conditions.

   **Normally De-Energized Relay —** A relay with its coil de-energized during normal operating conditions.

   **Normal Operating Conditions —** The operating condition when no alarms or special states are active.

   The normally energized/normally de-energized states of relay 6 are reversed in the on-board logic. Consequently, the jumper position for relay 6 is the opposite of the jumper positions for relays 1 through 5.

   Two example relay configurations are default and failsafe.

   (a) Default Configuration. The default configuration of the relays minimizes the amount of nuisance alarms during power interruptions to the instrument's electronics. This configuration also minimizes power usage and maximizes relay life during normal operations.

   In the default configuration, relays 1 through 5 are normally de-energized and normally open and relay 6 is normally energized and normally closed. Therefore, all six contacts are open during normal operating conditions and close when an alarm condition occurs. If a power failure occurs, relays 1 through 5 open and relay 6 closes.

   (b) Failsafe Configuration. The failsafe configuration of the relays places normally open relay contacts in a closed state during normal operating conditions and in an open state during an alarm or no power condition.

   In the failsafe configuration, all of the relays are normally energized and normally open. Therefore, all of the relay contacts are closed during normal operating conditions and open when an alarm or no power condition occurs.

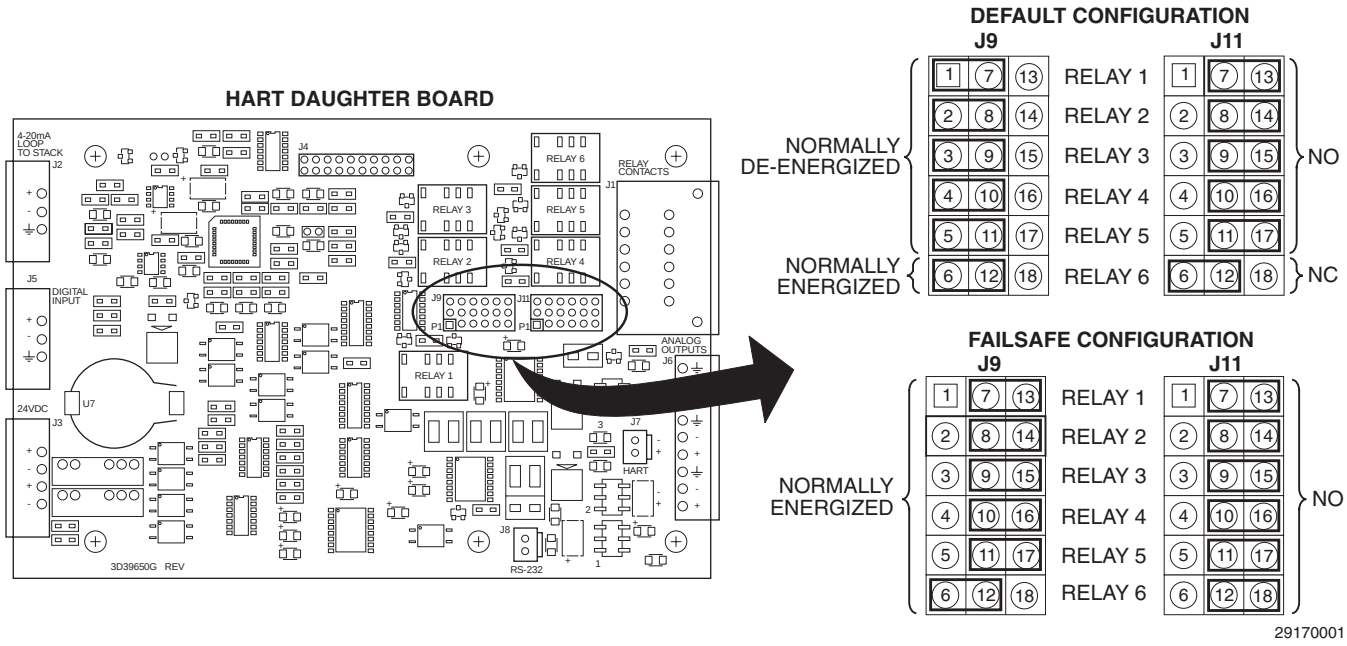



**Figure 3-4. HART Daughter Board Relay Contact Configurations**

**3-3. TYPE 4X INTELLIGENT ELECTRONICS (OPTION).** In addition to the IG-1 software board and the HART daughter board of the intelligent electronics unit, the Type 4X version (Figure 3-5) also includes a weatherproof enclosure, power supply, optional heater, and termination board.

**a. IG-1 Software Board.** The IG-1 software board (Figure 3-2 and 19, Figure 3-5) contains the software program, three LED indicators, and connections to the transceiver, power source, and HART daughter board (9).

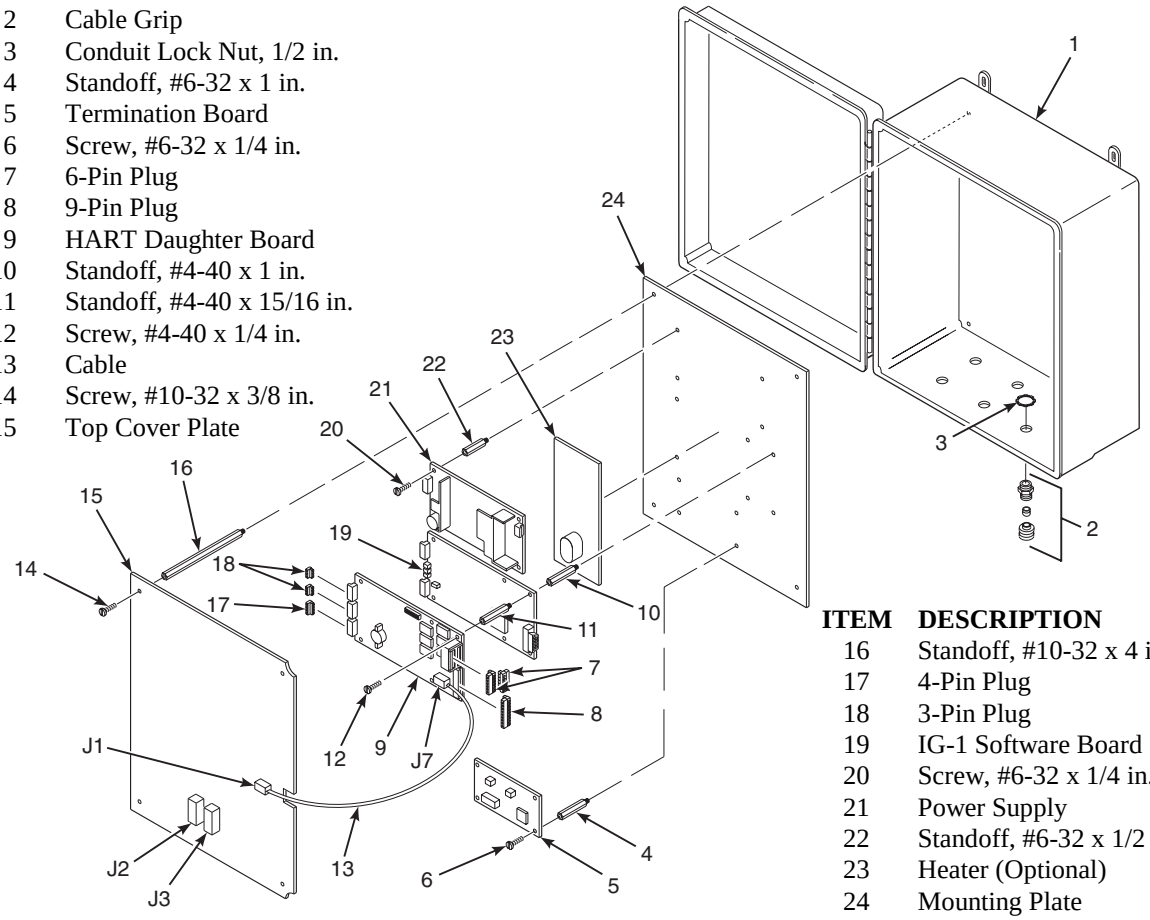
The Type 4X and the general purpose intelligent electronics units use the same software board. The only difference that exists is in the 24 VDC connection. The software board in the general purpose unit is wired directly to a 24 VDC power source; the software board in the Type 4X unit is wired to a universal power supply that transforms the incoming line voltage into the required 24 VDC.

**b. HART Daughter Board.** The HART daughter board (Figure 3-3 and 9, Figure 3-5) contains the real-time clock, relay jumper blocks, and connections to the transceiver, power source, HART Communicator, analog outputs, relay contacts, and digital input.

The general purpose and Type 4X units use the same HART daughter board, but two differences exist. The HART daughter board in the general purpose unit is wired directly to a 24 VDC power source; the HART daughter board in the Type 4X unit is wired to a universal power supply that transforms the incoming line voltage into the required 24 VDC.

The other difference is the HART Communicator connection location. On top cover plate (15) of the Type 4X unit are two banana jacks, J2 and J3, used to attach the HART Communicator to the 4-20 mA signal loop. These banana jacks connect to HART connector J7 on the HART daughter board via connector J1 on the top cover plate.

| ITEM | DESCRIPTION |
|---|---|
| 1 | Enclosure |
| 2 | Cable Grip |
| 3 | Conduit Lock Nut, 1/2 in. |
| 4 | Standoff, #6-32 x 1 in. |
| 5 | Termination Board |
| 6 | Screw, #6-32 x 1/4 in. |
| 7 | 6-Pin Plug |
| 8 | 9-Pin Plug |
| 9 | HART Daughter Board |
| 10 | Standoff, #4-40 x 1 in. |
| 11 | Standoff, #4-40 x 15/16 in. |
| 12 | Screw, #4-40 x 1/4 in. |
| 13 | Cable |
| 14 | Screw, #10-32 x 3/8 in. |
| 15 | Top Cover Plate |




| ITEM | DESCRIPTION |
|---|---|
| 16 | Standoff, #10-32 x 4 in. |
| 17 | 4-Pin Plug |
| 18 | 3-Pin Plug |
| 19 | IG-1 Software Board |
| 20 | Screw, #6-32 x 1/4 in. |
| 21 | Power Supply |
| 22 | Standoff, #6-32 x 1/2 in. |
| 23 | Heater (Optional) |
| 24 | Mounting Plate |

**Figure 3-5. Type 4X Intelligent Electronics - Exploded View**

**c.** **Type 4X Enclosure.** Enclosure (1, Figure 3-5) is weatherproof so the intelligent electronics can be installed outdoors. Top cover plate (15) provides convenient access to the 4-20 mA signal loop needed to attach the HART Communicator operator interface.

**d.** **Termination Board.** Termination board (5, Figure 3-5 and Figure 3-6) connects to the incoming line voltage and supplies the operating voltage to the power supply and heater. The 5 A, 250 V Slo Blo fuse on the termination board protects the system components from the incoming voltage.

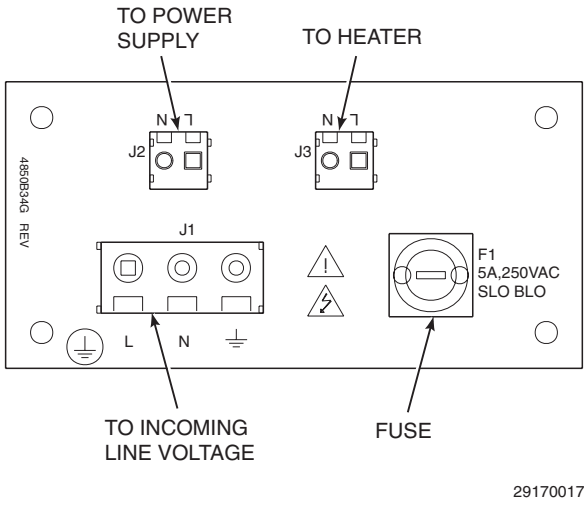



**Figure 3-6. Termination Board**

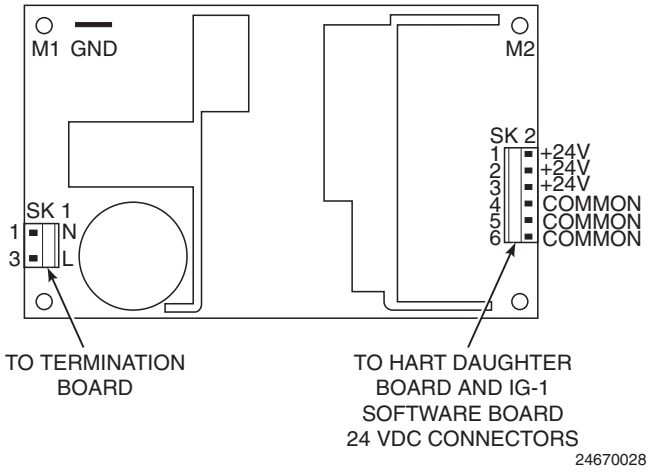
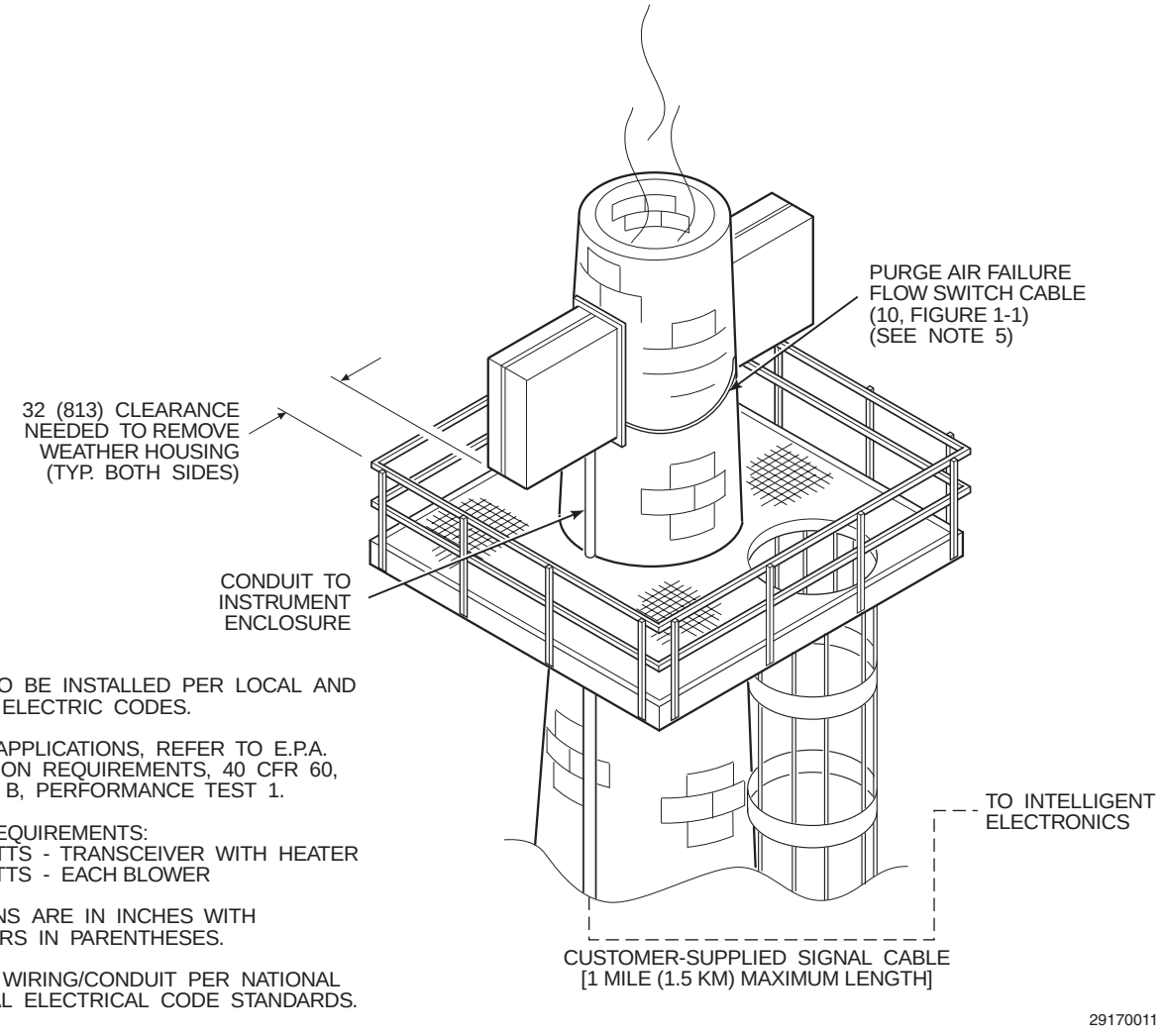



**Figure 3-7. Power Supply**

**e.** **Power Supply.** Universal power supply (21, Figure 3-5 and Figure 3-7) transforms the incoming line voltage into the 24 VDC used by the IG-1 software board and the HART daughter board. The power supply receives power through its connection to the termination board (Figure 3-6).

**f.** **Heater (Optional).** Optional 300 watt heater (23, Figure 3-5), available in 115 VAC or 220 VAC depending on the customer requirement, keeps the Type 4X unit components at an ambient operating temperature. If the ambient temperature falls below 60°F (16°C), the heater turns on. If the temperature rises above 75°F (24°C), the heater turns off. The heater receives power through its connection to the termination board (Figure 3-6).




NOTES:

1. SYSTEM TO BE INSTALLED PER LOCAL AND NATIONAL ELECTRIC CODES.
2. FOR U.S. APPLICATIONS, REFER TO E.P.A. INSTALLATION REQUIREMENTS, 40 CFR 60, APPENDIX B, PERFORMANCE TEST 1.
3. POWER REQUIREMENTS:
   400 WATTS - TRANSCEIVER WITH HEATER
   400 WATTS - EACH BLOWER
4. DIMENSIONS ARE IN INCHES WITH MILLIMETERS IN PARENTHESES.
5. CONNECT WIRING/CONDUIT PER NATIONAL AND LOCAL ELECTRICAL CODE STANDARDS.

**Figure 4-1. Transmitter Location Considerations**

# SECTION IV. INSTALLATION

**WARNING**

**Before starting to install this equipment, read the "Safety instructions for the wiring and installation of this apparatus" at the front of this Instruction Bulletin. Failure to follow the safety instructions could result in serious injury or death.**

**4-1.** **GENERAL.** Proper functioning of the Rosemount OPM 2000R Opacity/Dust Density Transmitter depends on proper installation. All procedures in this section must be followed carefully.

**4-2.** **CHOOSING A LOCATION.** The location of the OPM 2000R is important for obtaining maximum accuracy in the reading of the stack particulates. Keep in mind both clearance and process/regulatory considerations.

**a. Clearance Considerations.**

1. Ensure the location is accessible and provides adequate clearance to service and maintain the transmitter.

2. Allow 32 in. (813 mm) for clearance on each side of the stack to remove and install the weather housings (Figure 4-1).

3. Locate the transmitter no further than one mile (1.5 km) from the intelligent electronics.

**b. Regulatory/Process Considerations.** The EPA has established the following guidelines for choosing an opacity/dust density transmitter installation site:

1. Locate the transmitter across a section of a duct or stack that will provide a particulate matter flow through the path of the transmitter beam representative of the duct or stack flow.

2. Ensure the transmitter location is downstream from all particulate control equipment.

3. Locate the transmitter as far from bends and obstructions as practical.

4. If a transmitter is to be located less than 4 duct diameters downstream from a bend, install the transmitter in the plane defined by the bend. See Figure 4-2.

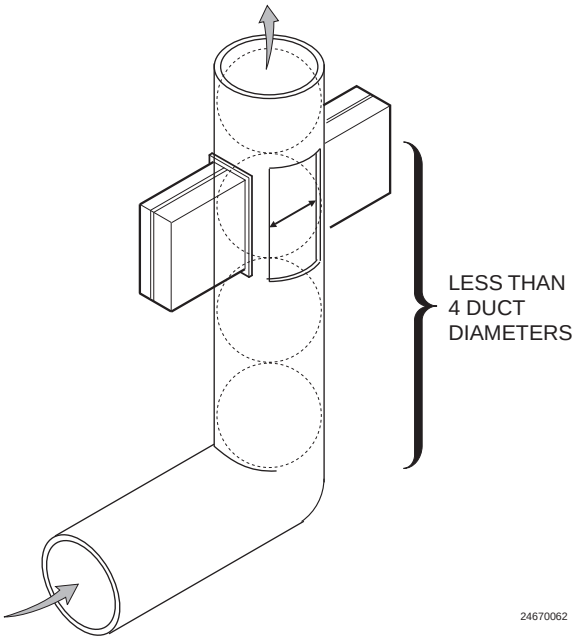



**Figure 4-2. Transmitter Location**

5. Ideally, locate the transmitter eight to ten stack diameters upstream from the stack exit and three to five diameters downstream from any bends, junctions, or other constrictions in the stack or duct.

   For best results, mount the transceiver and retroreflector modules so the light beam is exactly perpendicular to the stack or duct and the beam goes through the center. Do not install the transmitter downstream of a wet scrubber. The water droplets introduced to the gas stream by such equipment will interfere with the opacity readings. For an accurate measurement under these conditions, choose a location upstream from a wet scrubber or a location downstream from the scrubber where the water droplets are vaporized by the reheating of the gas.

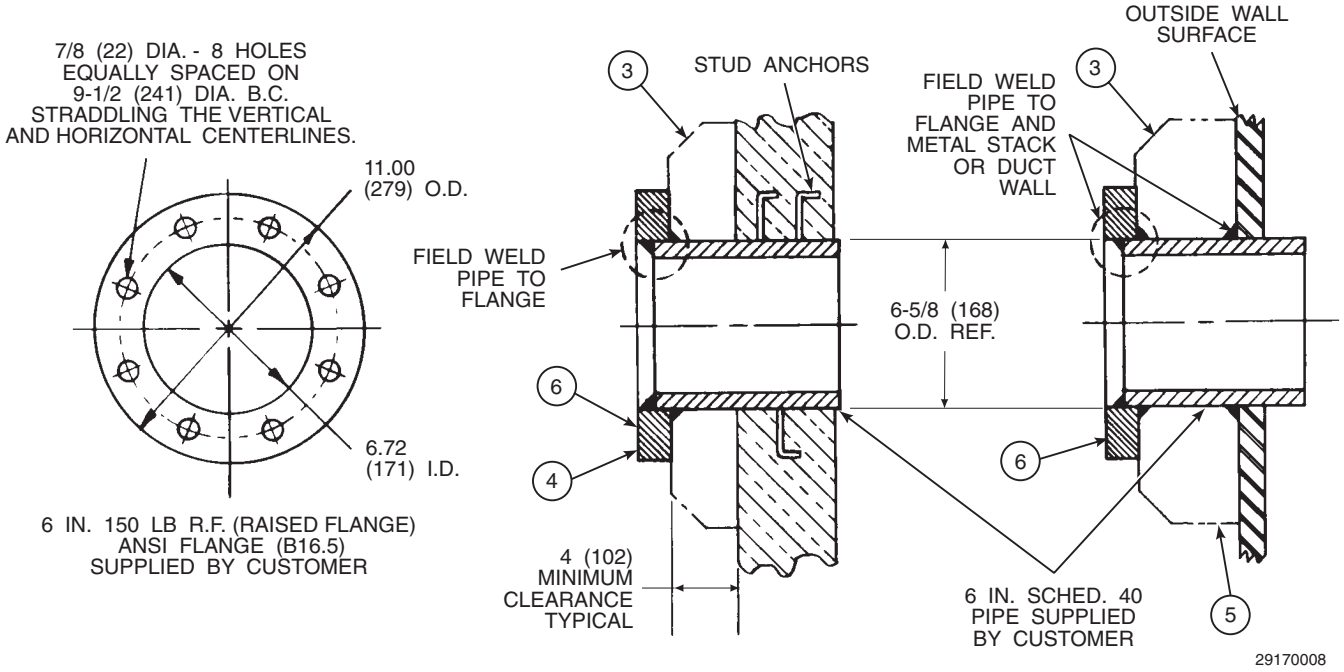
**4-3. CALIBRATION.** The OPM 2000R is factory calibrated for the flange-to-flange distance (*lf*) (Figure 1-3) of the installation site. If the unit needs to be recalibrated, refer to paragraph 6-7.b. If a Dust Concentration (DC) output is required after installation, it is necessary to perform isokinetic sampling on the flue gas while simultaneously measuring the extinction (E) value. Refer to paragraph 1-3 for a description of this procedure.

**4-4. MOUNTING FLANGES TO STACK.**

**a.** Form two mounting holes in the stack at locations specified in paragraph 4-2. Holes must be on the same horizontal and vertical axes. A liquid level can be used to ensure that modules are installed on same horizontal plane.

**b.** Install 6 in. pipe and 6 in., 150 lb flanges following the notes in Figure 4-3. Pipe must be horizontal and should protrude at least 4 to 6 in. (102 to 153 mm).

**c.** Weld a flange to each pipe. Align flanges so that they are relative to a common centerline. Total module deviation should not exceed ±5 degrees. Deviation within this limit can be compensated for by the air lens ball joint adjustment.




**MASONRY STACK WALL INSTALLATION**

**METAL WALL STACK OR DUCT INSTALLATION**

NOTES: 1. DIMENSIONS ARE IN INCHES WITH MILLIMETERS IN PARENTHESES.

2. ALL MATERIAL AND FIELD WORK ARE PROVIDED BY THE CUSTOMER TO INSTALL THE TRANSCEIVER AND RETROREFLECTOR MODULES OF THE OPACITY MONITOR.

3. WHEN FLUE GAS TEMPERATURE IS LESS THAN 600°F (316°C), INSULATE AND LAG THIS AREA TO PREVENT CONDENSATION AND CORROSION.

4. A BLANK 11.0 IN. (279 MM) O.D. BLIND 150 LB FLANGE DRILLED TO A 6.72 IN. (171 MM) I.D. AND DRILLED AND TAPPED TO 0.75 - 16 UNF (M20) - 8 HOLES EQUALLY SPACED ON 9.50 IN. (241 MM) DIA. B.C. MAY BE SUBSTITUTED FOR THE 6 IN. 150 LB RF FLANGE.

5. EXTEND INSULATION ON METAL STACK OR DUCT SURFACES TO 24 IN. (610 MM). THIS WILL PREVENT RADIANT HEAT FROM DAMAGING THE OPACITY MONITOR.

6. WHEN FLUE GAS TEMPERATURE EXCEEDS 600°F (316°C), INSERT AN INSULATING GASKET SUCH AS MANUFACTURED BY BNZ MATERIALS, INC. RECOMMENDED GASKET MATERIAL IS MARINITE P, AT LEAST 1 IN. (25 MM) THICK. REFER TO PARAGRAPH 4-7.b.1 REGARDING THERMO ISOLATORS.

**Figure 4-3. Stack Flange Installation**

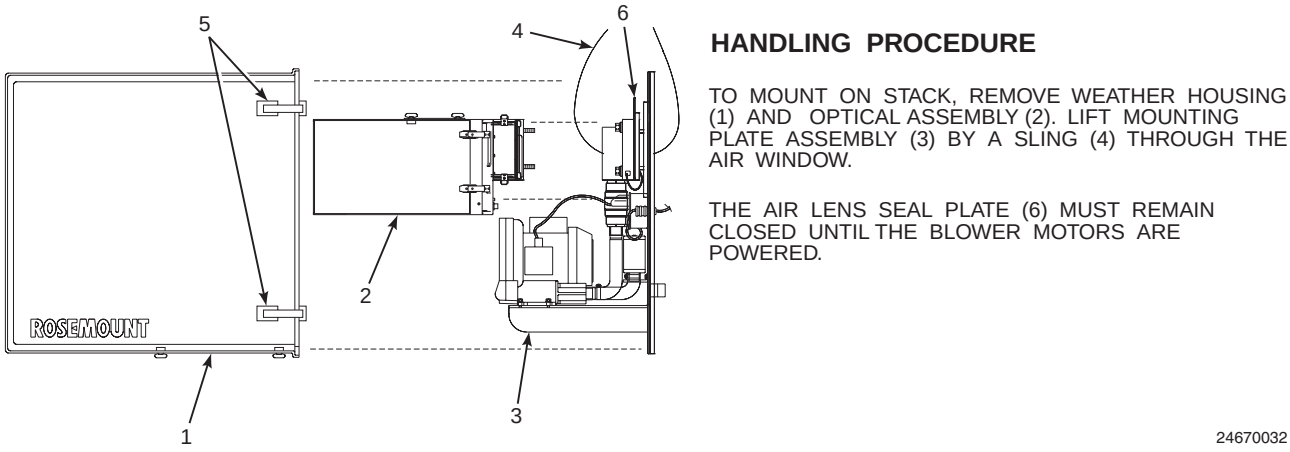



**Figure 4-4. Lifting and Handling**

**4-5. LIFTING AND HANDLING.** Use the following procedure to hoist the modules to the installation site and mount them to the stack:

**a.** Remove the weather housings by releasing the four toggle clamps (5, Figure 4-4) that hold each housing to the mounting plate.

**b.** Remove transceiver optical assembly or retroreflector from air lens assembly (Figures 2-1 and 2-12).

**c.** Run a lifting sling through the air lens opening in the mounting plate (Figure 4-4). Make sure all hooking devices are secure. Lift the mounting plate assembly to the installation site.

**4-6. MOUNTING INSTRUCTIONS.**

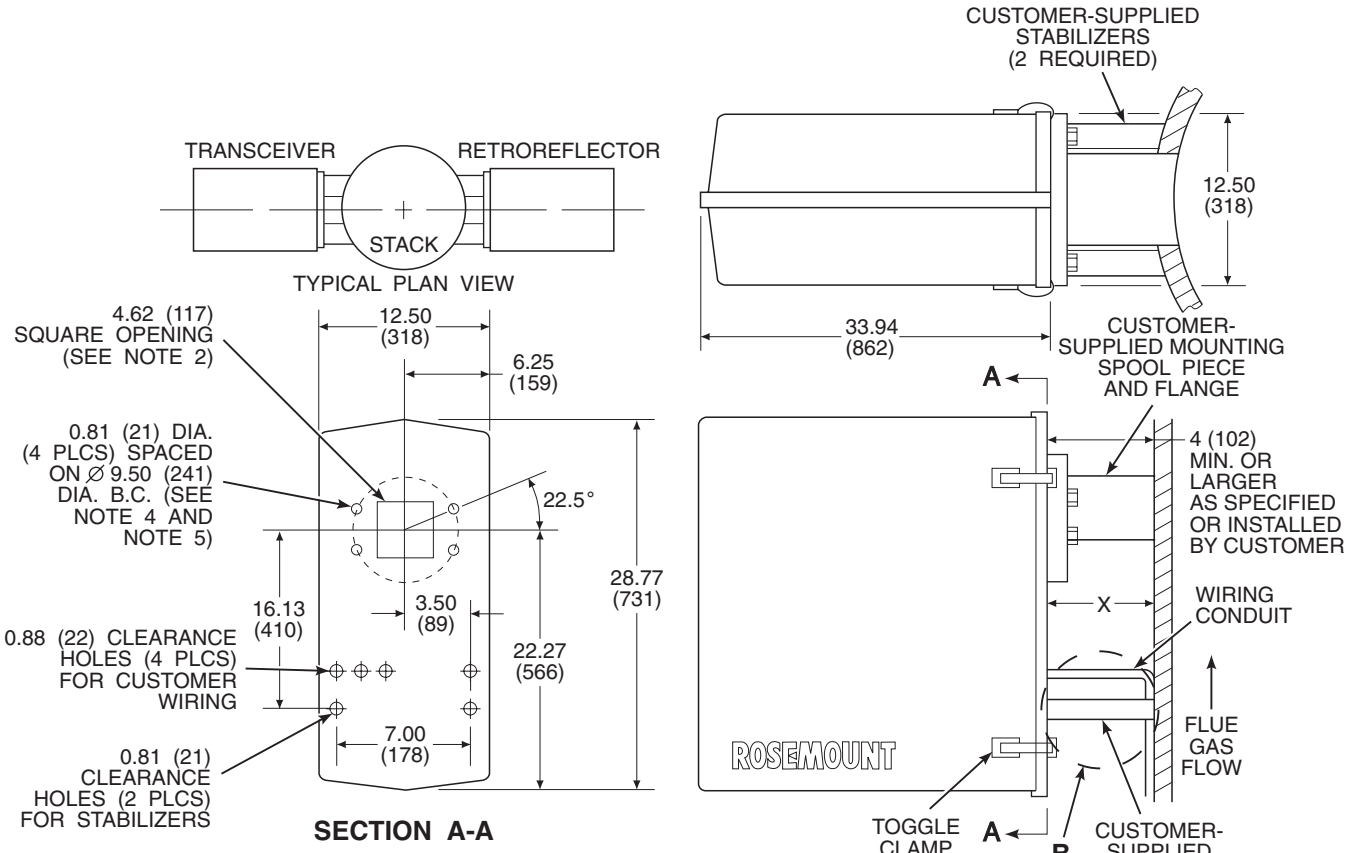
**a. Transceiver and Retroreflector Modules.**

1. Install customer-supplied 0.75-16 bolts in the stack mounted spool piece and flange for the mounting plate per Figures 4-3 and 4-5.
2. Make sure heat-resistant gasket (32, Figure 2-1) is installed between each module and its stack flange. Attach each module to the four bolts installed in each stack flange and secure with four customer-supplied washers and nuts.
3. Install stabilizers to provide firm support for each module and secure with customer-supplied bolts, nuts, and washers from the inside of the mounting plate (Figure 4-5).

**CAUTION**

**Shutter must remain closed until the blower is powered up.**

4. Close air lens assembly shutter (seal plate) (6, Figure 4-4) until the blowers are powered up.
5. Install the transceiver optical assembly and retroreflector to the mounting plates and install the weather housings to the modules (Figure 4-5).




NOTES:

1. DIMENSIONS ARE IN INCHES WITH MILLIMETERS IN PARENTHESES.
2. MOUNTING PLATE OPENING TO STACK.
3. FOUR TOGGLE CLAMPS ARE PROVIDED TO ATTACH MOUNTING PLATE TO WEATHER HOUSING.
4. 0.75-16 UNF X 3.0 (M20 X 75 MM) HEX HEAD BOLTS WITH WASHERS AND NUTS (CUSTOMER-SUPPLIED) REQUIRED TO ATTACH INSTRUMENT TO 6 IN. 150 LB ANSI FLANGE.
5. BOLT HOLE PATTERN TO CUSTOMER FLANGE STRADDLES THE CENTERLINE. MOUNTING FLANGE AND BOLTS ARE CUSTOMER-SUPPLIED.
6. SYSTEM TO BE INSTALLED PER LOCAL AND NATIONAL ELECTRIC CODES.
7. FOR U.S. APPLICATIONS, REFER TO E.P.A INSTALLATION REQUIREMENTS, 40CFR60, APPENDIX B, PERFORMANCE TEST 1.

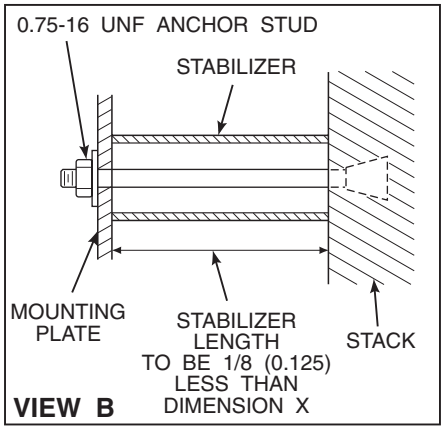



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**Figure 4-5. Stack Installation Dimensions**

**b. Intelligent Electronics.** The outline drawings in Figure 4-6 show the mounting centers and clearances for the two versions of the intelligent electronics.

1. General Purpose Intelligent Electronics.

   (a) Install the general purpose intelligent electronics no further than 1 mile (1.5 km) from the stack-mounted transceiver unit.

   (b) Due to the type of enclosure, the general purpose unit must be installed indoors where the ambient temperature is between 40° to 120°F (4° to 50°C).

   (c) If mounting the unit on a wall or bulkhead, use cable clamps and straps on the wiring as needed to avoid straining the connections.

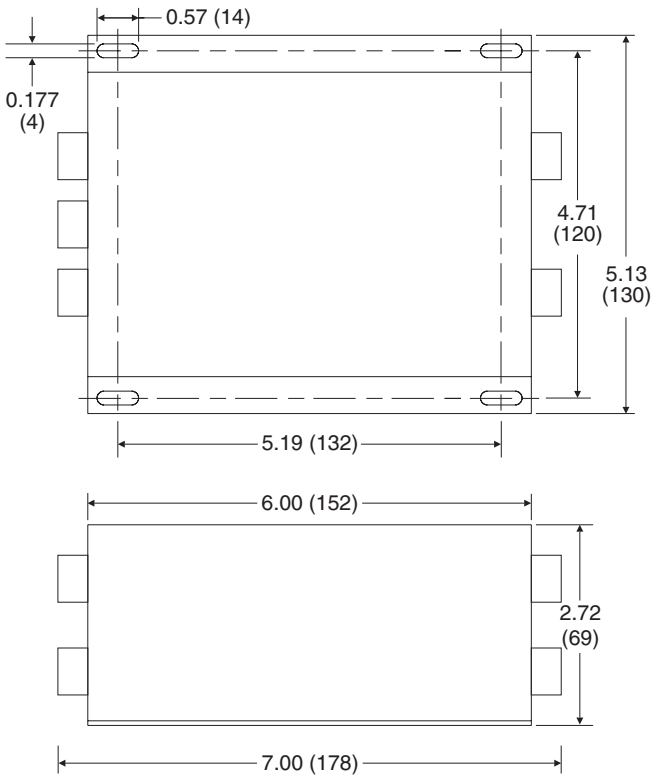
2. Type 4X Intelligent Electronics.

   (a) Mount the Type 4X intelligent electronics to a wall or bulkhead no further than 1 mile (1.5 km) from the stack-mounted transceiver unit.

   (b) Locate units without the optional heater where the ambient temperature is between 40° to 120°F (4° to 50°C). For units with the optional heater, install where the ambient temperature is between -40° to 120°F (-40° to 50°C). Keep in mind that the Type 4X version can also be installed outdoors.

**c. Model 751 Indicator (Optional).** If using the Model 751 indicator, mount in an accessible location per the instructions in document PDS 4378A00.

**GENERAL PURPOSE INTELLIGENT ELECTRONICS**




NOTE: DIMENSIONS ARE IN INCHES
WITH MILLIMETERS IN PARENTHESES.

**TYPE 4X INTELLIGENT ELECTRONICS**

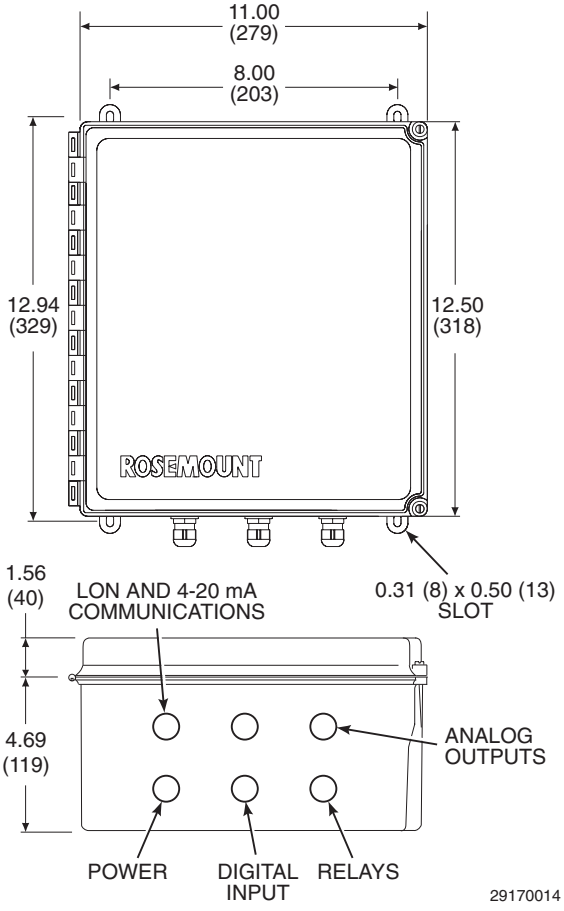



**Figure 4-6. Intelligent Electronics Mounting Dimensions**

## 4-7. MONITORING OPACITY IN HIGH TEMPERATURE APPLICATIONS.

**a. Introduction.** Measuring opacity in high temperature applications such as incinerators can be detrimental to the physical well-being of opacity transmitters. Flue gases from incinerators approach 2000°F (1093°C). Opacity transmitters have reportedly "melted" at these high temperatures.

Other less severe temperatures just over 400°F (204°C) can also cause opacity transmitter operation problems. In these applications, the opacity transmitter is mounted to a steel duct or steel stack. Radiant heat from the duct or stack can cause the temperature within the transceiver and retroreflector modules to exceed ambient temperature limits.

**b. Solution.** The heat at the opacity transmitter must be reduced to permit accurate opacity monitoring in these applications. Rosemount Analytical offers several solutions to help with these applications.

1. Thermo Isolators. Thermo isolators should be used whenever the stack temperature is above 600°F (316°C): for example, incinerator and hot steel stack applications. They provide a heat-resistant barrier between the stack and opacity transmitter flanges. Thermo isolators are a must with the higher temperature incinerators.

   Rosemount Analytical offers thermo isolators for the OPM 2000R's 6 in. mounting flanges. This 1 in. (25.4 mm) thick high-temperature gasket provides sufficient thermo isolation to withstand hot face temperatures of 1700° to 1800°F (927° to 982°C). Two thermo isolators are required for each OPM 2000R. Remember to add 2 in. (51 mm) to the flange-to-flange dimension *(lf)* when thermo isolators are used.

   In addition, insulation and a cooling fin (Figure 4-7) can be installed between the duct and the opacity transmitter to ward off radiant heat. This barrier is recommended for high radiant heat applications as found in incinerators and hot steel stacks.

2. Purge Air. A duct or stack maximum pressure is limited to plus 10 in. WC in order to supply a minimum flow of 40 SCFM purge air. These constraints must also be adhered to for this application to be successful. A flow of cool purge air must be maintained or the opacity transmitter may suffer heat damage.

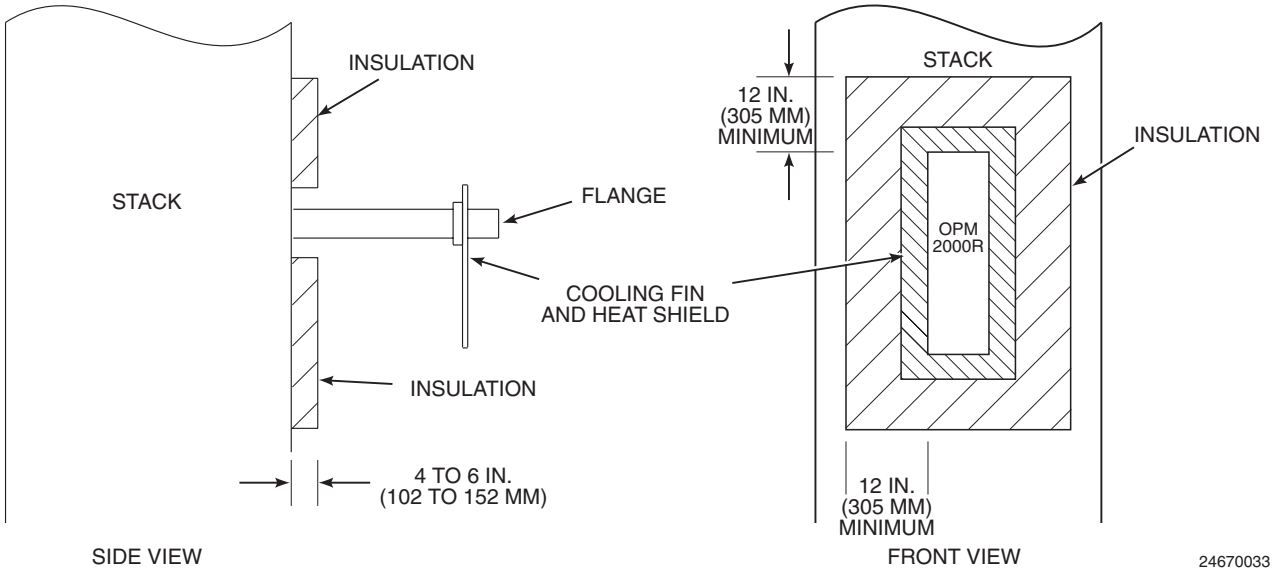



**Figure 4-7. Insulation and Cooling Fin Installation**

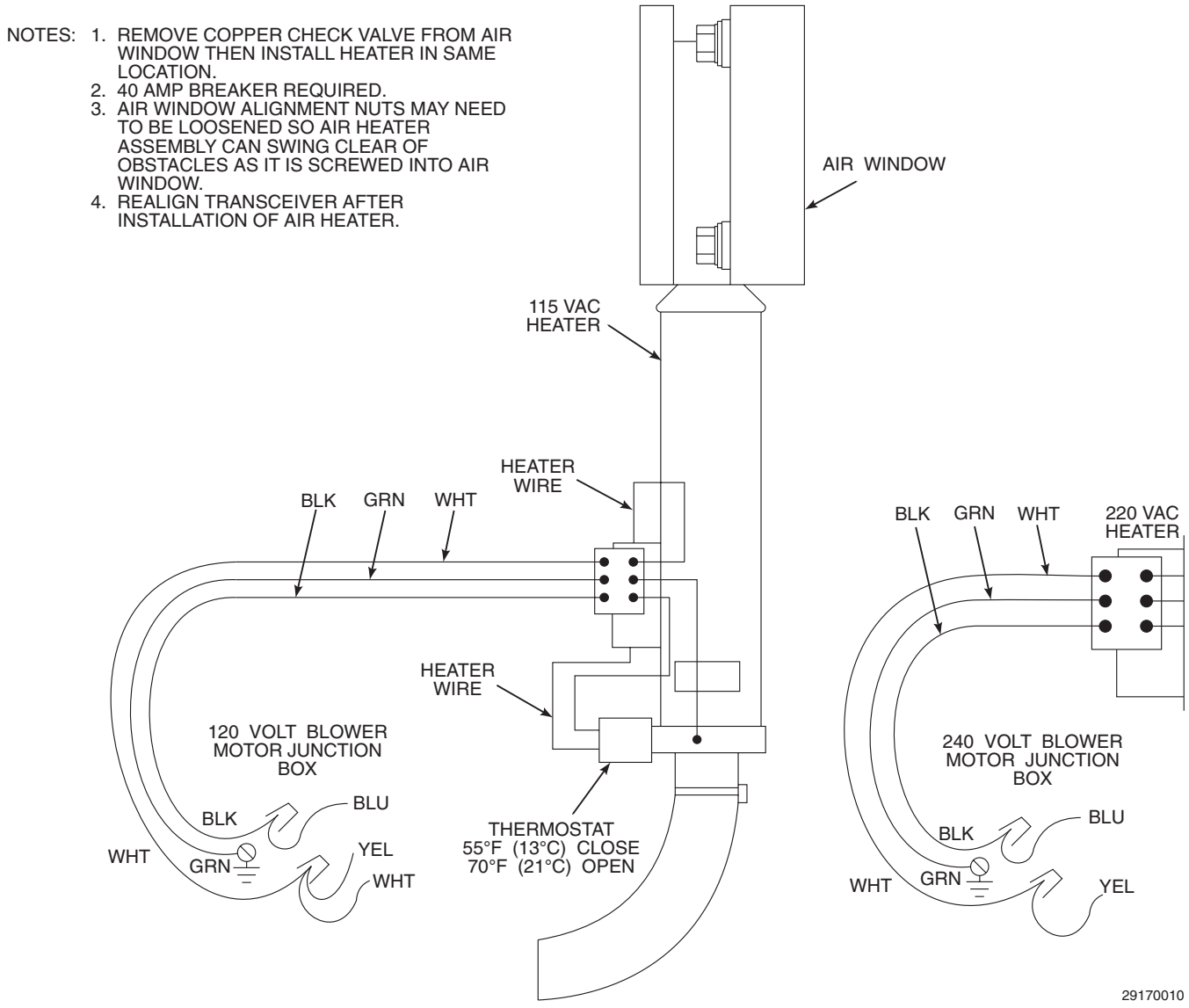



**Figure 4-8. Optional Purge Air Heater**

## 4-8. MONITORING OPACITY AT LOW AMBIENT TEMPERATURES.

**a. Introduction.** Measuring opacity in locations where ambient temperatures can be expected to go below -20°F (-28.9°C) can cause false readings as a result of the extremely cold ambient air being used by the purge air blowers. When extremely cold purge air mixes with the hot process gases, "fogging" can occur. This phenomenon takes place at the outlet of the purge air window assembly and directly in the path of the opacity measurement. As a result, the opacity reading is falsely represented as a higher than expected value due to the presence of the fog.

**b. Solution.** The OPM 2000R can be ordered and/or field retrofitted with purge air heaters. This heater mounts between the blower and the purge air window assembly in place of the check valve and elevates the temperature of the purge air to prevent fogging. Refer to Figure 4-8.

## 4-9. SYSTEM WIRING INSTALLATION.

**a. Wiring Practices.** The wire selected for supplying power to the intelligent electronics and modules must be sized to meet the current carrying requirements (capacity) for the application. Refer to the specifications in paragraph 1-4. The National Electrical Code contains tables that may be used as a guide. Voltage classification must be equal to or exceed the rated circuitry voltage.

All customer-supplied wiring must conform to standard wiring practices in accordance with local code. The wire must be able to withstand the physical stresses to which it may be subjected during installation.

**NOTE**

**If wiring an OPM 2000R with a general purpose intelligent electronics, refer to Figure 4-9. If wiring an OPM 2000R with a Type 4X intelligent electronics, refer to Figure 4-10.**

**b.** **Transceiver Module.** Refer to Figure 4-9 or Figure 4-10 as appropriate.

1. Make sure communications cable (3, Figure 2-1) from the transceiver is plugged into connector J2 on the stack termination board.
2. Make sure power cable (2, Figure 2-1) from the transceiver is plugged into connector J4 on the stack termination board.
3. Attach the customer-supplied signal cable to HART and LON connectors J1 and J5 on the stack termination board. Run the cable through the cable grip in the mounting plate and tighten the seal onto the cable.
4. Make sure cable (53, Figure 2-1) from the transceiver purge air failure flow switch is connected to PR SW 1 connector J7 on the stack termination board.

**CAUTION**

**Check transceiver data plate for the actual voltage rating. Failure to connect the power cable to the appropriate power source will damage equipment.**

5. Attach a line voltage power cable to AC IN connector J3 on the stack termination board. Run the cable through the cable grip in the mounting plate. Tighten the seal onto the cable. Connect the power cable to a suitable line voltage power source.
6. Refer to paragraph 6-2 for the procedure to connect the HART communicator to the 4-20 mA signal loop at the transceiver location.

**c.** **Retroreflector Module.** Refer to Figure 4-9 or Figure 4-10 as appropriate. Run a customer-supplied cable from PR SW 2 connector J8 on the transceiver stack termination board through a cable grip in the transceiver mounting plate to the purge air failure flow switch in the retroreflector module as shown in Figure 4-1. Tighten both seals at each end of the cable. Connect the wires to the retroreflector purge air failure flow switch.

**d.** **Blower Motor.** Refer to Figure 4-9 or Figure 4-10 as appropriate.

**NOTE**

**The retroreflector blower motor has its own independent power source but is wired the same as the transceiver blower motor at the motor junction box.**

1. Run a line voltage power cable, depending on the system application, through a cable grip on the retroreflector mounting plate to the retroreflector blower motor.
2. Connect the wires at the blower motor junction box.
3. Tighten the cable seal.

**e.** **General Purpose Intelligent Electronics.** Refer to Figure 4-10.

**NOTE**

**Relay jumper blocks J9 and J11 on the HART daughter board can be configured for either the default or failsafe configuration. For more information, refer to Section III, INTELLIGENT ELECTRONICS.**

1. Run the customer-supplied signal cable through a suitable conduit.
2. Connect the signal cable to the 4-20 mA TO STACK and LON connectors on the intelligent electronics.

**CAUTION**

**Check the intelligent electronics data plate for the required intelligent electronics voltage. Connecting the unit to the wrong supply voltage will damage the equipment.**

3. Attach a customer-supplied 24 VDC power cable to the two +24 V connectors on the unit. If a 24 VDC power source is not available, attach the optional universal power supply to the two +24 VDC connectors and plug the power supply into the customer-supplied voltage source.
4. Connect a customer-supplied digital input cable for remote initialization of zero/span checks to the DIGITAL INPUT connector on the intelligent electronics.

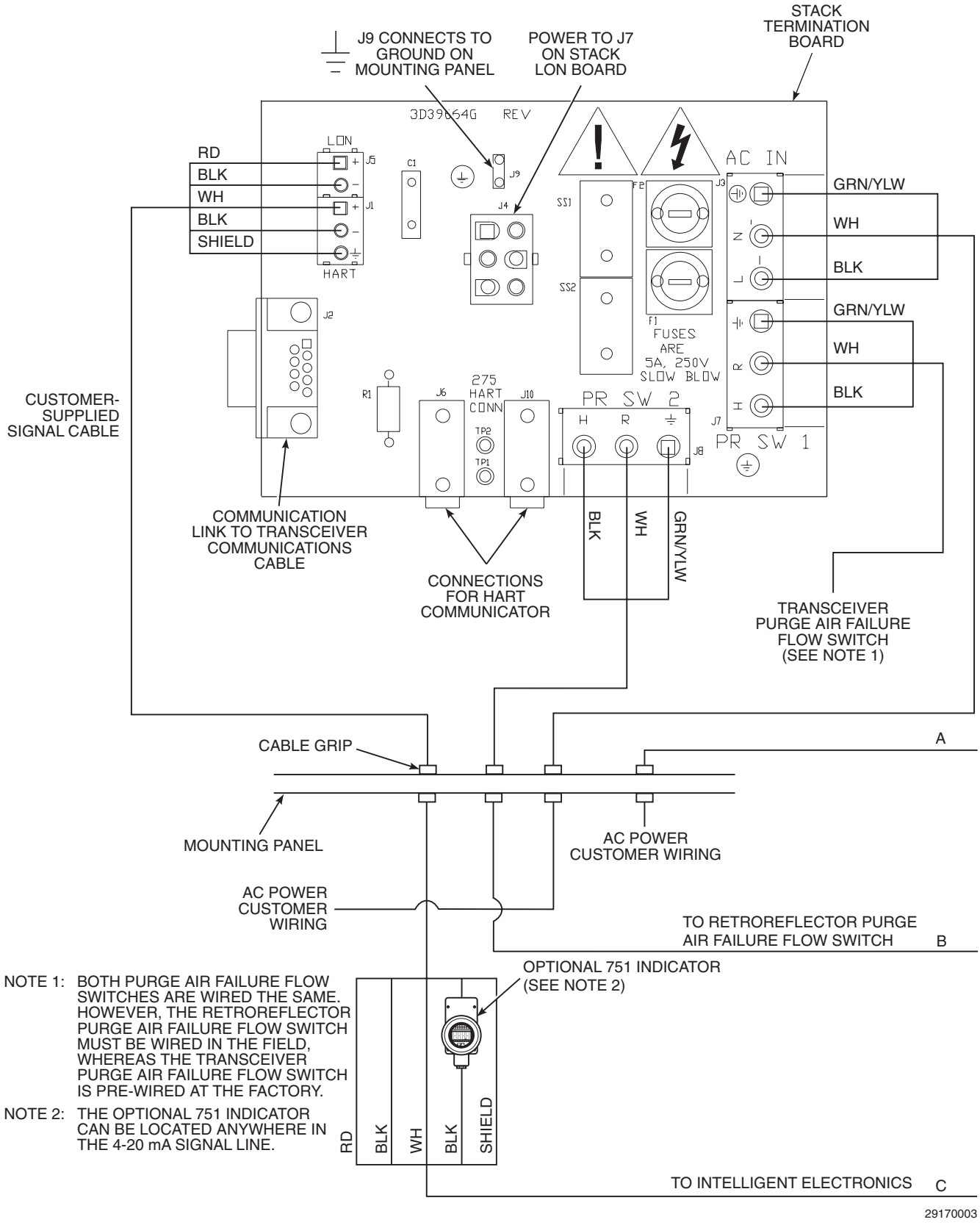



**Figure 4-9. Customer Connections for OPM 2000R with General Purpose Intelligent Electronics (Sheet 1 of 2)**

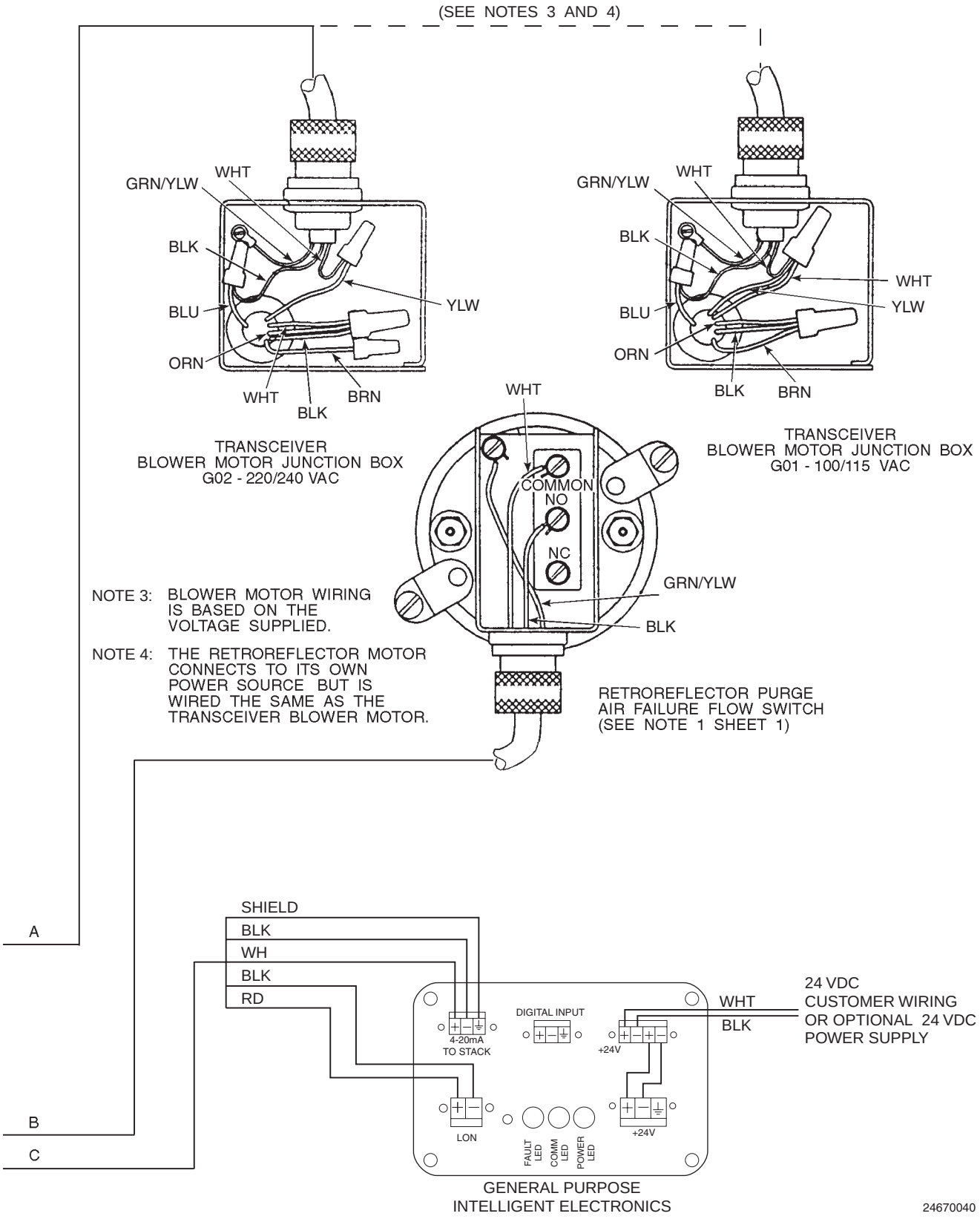



**Figure 4-9. Customer Connections for OPM 2000R with General Purpose Intelligent Electronics (Sheet 2 of 2)**

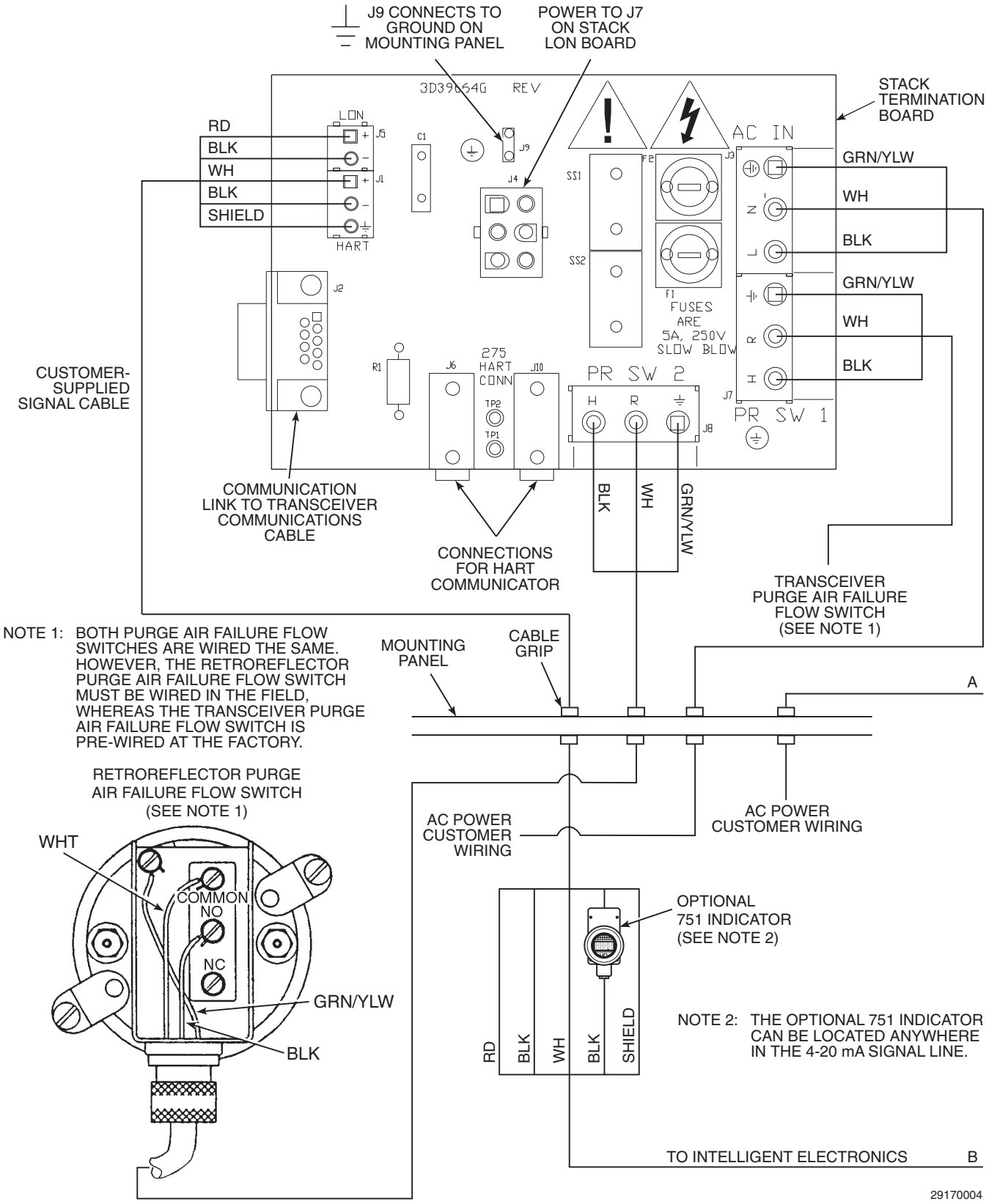



**Figure 4-10. Customer Connections for OPM 2000R with Optional Type 4X Intelligent Electronics (Sheet 1 of 2)**

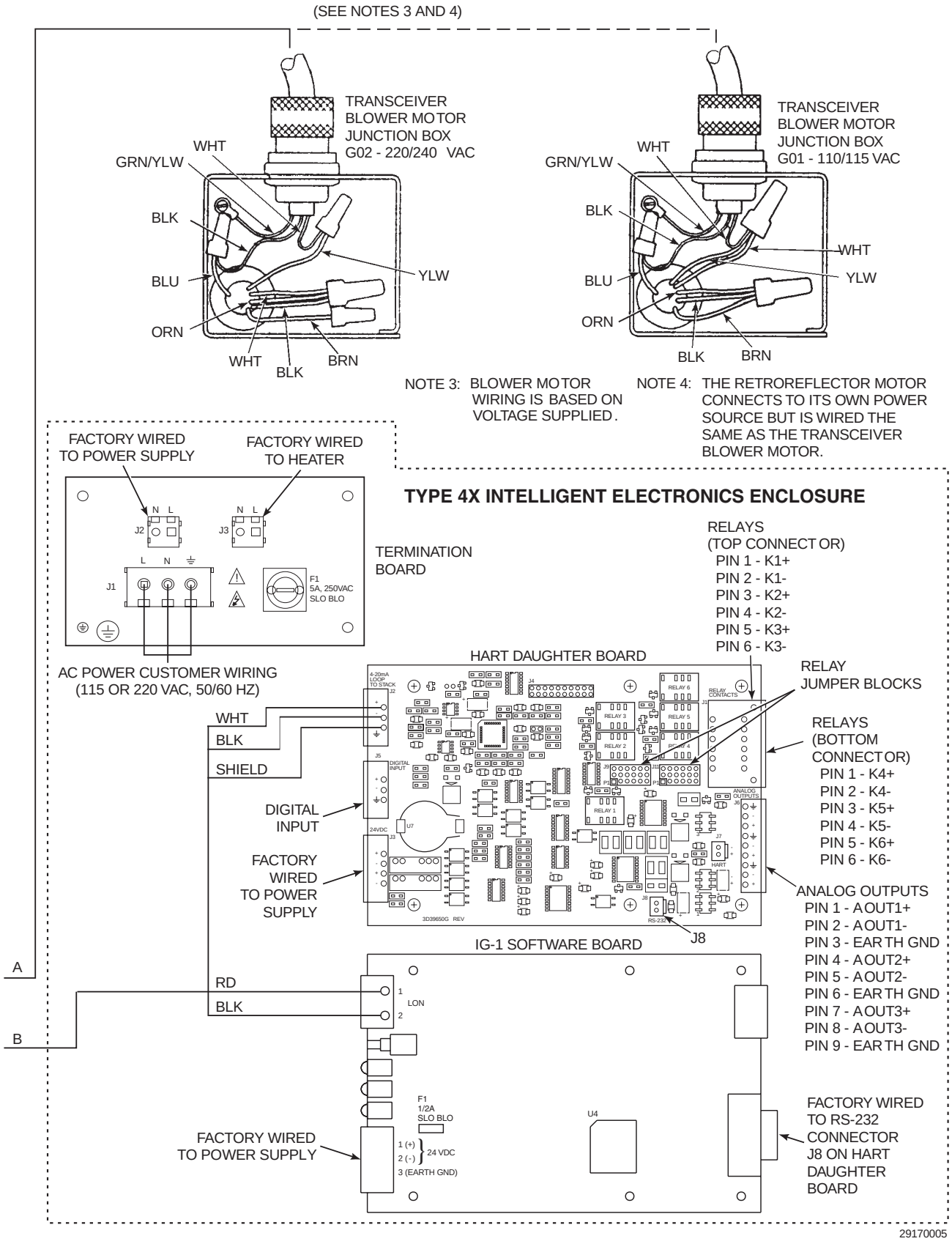



**Figure 4-10. Customer Connections for OPM 2000R with Optional Type 4X Intelligent Electronics (Sheet 2 of 2)**

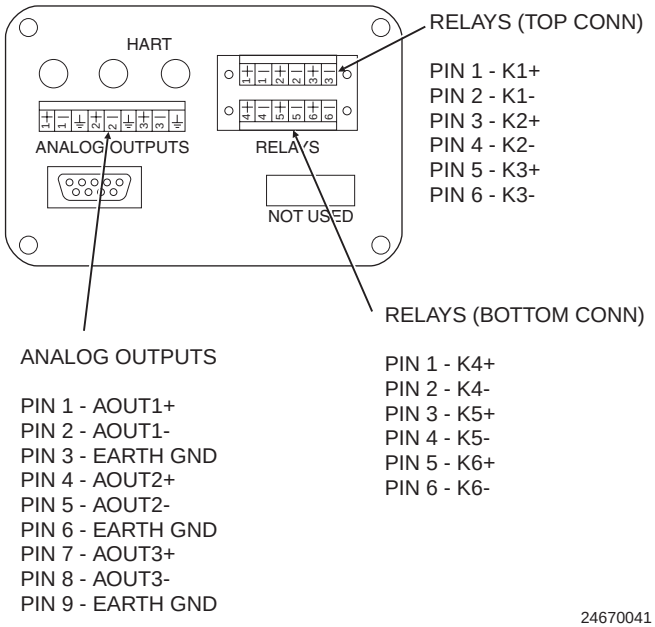



**Figure 4-11. General Purpose Intelligent Electronics Relay and Analog Output Connections**

5. Connect a customer-supplied relay output cable to the RELAYS connector on the intelligent electronics. Refer to Figure 4-11 to match the terminals to the relay functions.

6. Connect a customer-supplied analog output cable to the ANALOG OUTPUTS connector as shown in Figure 4-11. If any analog output is unused, connect a 250 ohm resistor between the (+) and (-) terminals.

**f. <u>Type 4X Intelligent Electronics (Optional)</u>.**

**NOTE**

**Relay jumper blocks J9 and J11 on the HART daughter board (Figure 4-10) can be configured for either the default or failsafe configuration. For more information, refer to Section III, INTELLIGENT ELECTRONICS.**

1. Run the customer-supplied signal cable through a suitable conduit.

2. Run the signal cable through the cable grip specified in Figure 4-6.

3. Connect the signal cable to the LON connector on the IG-1 software board and the 4-20 mA LOOP TO STACK connector on the HART daughter board as shown in Figure 4-10.

4. Once the cable is connected, tighten the cable seal.

**CAUTION**

**Check the intelligent electronics data plate for the required intelligent electronics voltage. Connecting the unit to the wrong supply voltage will damage the equipment.**

5. Run a customer-supplied 115 VAC or 220 VAC power cable, depending on the power source, through the cable grip specified in Figure 4-6. Connect the power cable to connector J1 on the Type 4X intelligent electronics termination board as shown in Figure 4-10. Once the cable is connected, tighten the cable seal.

6. Make sure connector J2 on the Type 4X intelligent electronics termination board connects to power supply connector SK1.

7. Make sure power supply connector SK2 connects to the 24 V connectors on the IG-1 software board and HART daughter board.

8. If the optional heater is installed, make sure connector J3 on the Type 4X intelligent electronics termination board connects to the heater.

9. Run a customer-supplied digital input cable for remote initialization of zero/span checks through the cable grip specified in Figure 4-6. Connect the cable to the DIGITAL INPUT connector on the HART daughter board as shown in Figure 4-10. Once the cable is connected, tighten the cable seal.

10. Run a customer-supplied relay output cable through the cable grip specified in Figure 4-6. Connect the cable to the RELAY CONTACTS connector on the HART daughter board. Refer to Figure 4-10 to match the terminals to the relay functions. Once the cable is connected, tighten the cable seal.

11. Run a customer-supplied analog output cable through the cable grip specified in Figure 4-6. Connect the cable to the ANALOG OUTPUTS connector on the HART daughter board. Once the cable is connected, tighten the cable seal.

**g. <u>Model 751 Indicator (Optional)</u>.** Attach the Model 751 indicator in series with the 4-20 mA signal loop. See Figure 4-10.

# SECTION V. ALIGNMENT

## 5-1. OPTICAL ALIGNMENT.

**CAUTION**

**Thermal deformation of the stack or duct can affect the accuracy of the alignment. To reduce the effects of thermal deformation, ensure the wall of the stack or duct is stabilized at the normal operating temperature prior to performing the final alignment procedure.**

**Stack gases can cause serious damage to the opacity monitor. To prevent damage to the unit, ensure purge air is on prior to opening the air lens seal plates. Ensure the seal plates are closed whenever the purge air blower is not running.**

**a.** Turn on power to the transceiver and retro-reflector.

**b.** Run the process long enough to stabilize the stack walls at normal operating temperature. The stack walls must be at the same temperature during final alignment as during the operation since thermal distortion of the walls can affect alignment.

**c.** Enter the check optics mode as follows:

1. Attach the HART Communicator and turn on the device. Refer to paragraph 6-2 for HART Communicator installation information.
2. From the online menu, select DEVICE SETUP.
3. Next, select DIAG/SERVICE from the DEVICE SETUP menu.
4. From the DIAG/SERVICE sub-menu, select CHECK OPTICS.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the CHECK OPTICS procedure may result in undesired equipment performance.**

5. A "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any automatic control loops and press OK to continue. Then, an "About to begin check optics" status message briefly displays.
6. In the next screen, the system prompts you to select the LCW state. Select the $V_{STACK}$ option. The present $V_{STACK}$ value will display. Proceed to the stack. A steady beam of light should be leaving the transceiver.

**d.** At the stack, use a screwdriver to pry open the latches on the weatherproof housings and remove the weather housings from the transceiver and retroreflector.

**e.** Verify that each purge air blower is running properly.

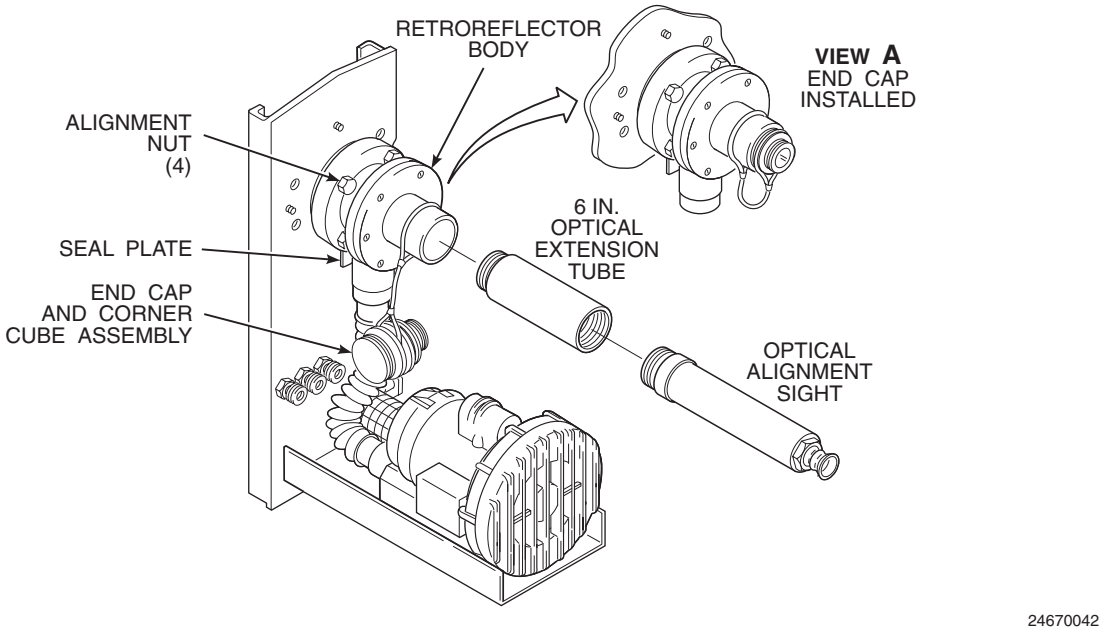



**Figure 5-1. Optical Alignment**

**f.** Push down the seal plates on both the transceiver and retroreflector to open the purge air path to the flue, but do not remove the air lens seal plates (Figure 5-1).

**g.** Align the transceiver as follows:

1. Remove the end cap and corner cube assembly from the retroreflector body.

2. Attach the optical alignment sight (without the extension tube) to the retroreflector body.

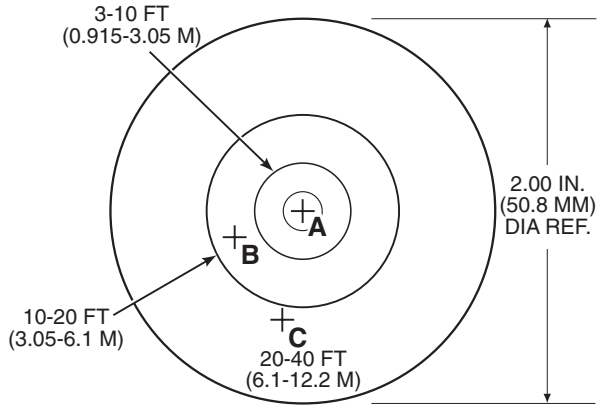
**NOTE**

**Three concentric areas are visible through the alignment sight. Longer pathlengths use the larger diameter circles.**

3. Observe the crosshair image projected by the transceiver onto the alignment sight. Note that three concentric areas provide tolerance definition for three different pathlength ranges (Figure 5-2).

4. Refer to Figure 5-2. If the crosshair intersection is within the concentric area for the given pathlengths, the unit is aligned within ±2% opacity.

**h.** If the crosshair intersection is not in the center of the circles, adjust the ball joint in the transceiver module using the four alignment nuts (Figure 5-1).




THE FIGURE ILLUSTRATES TOLERANCE AREAS FOR THREE PATHLENGTH RANGES. THE THREE EXAMPLE READINGS (FROM THREE DIFFERENT ALIGNMENTS) ARE AS FOLLOWS:

A - WITHIN ±2% OPACITY FOR ALL PATHLENGTHS.

B - WITHIN ±2% OPACITY FOR PATHLENGTHS ≥10 FT (≥3.05 M), BUT OUT OF ALIGNMENT FOR PATHLENGTHS <10 FT (<3.05 M).

C - WITHIN ±2% OPACITY FOR 20 TO 40 FT (6.1 TO 12.2 M) PATHLENGTHS, BUT OUT OF ALIGNMENT FOR SHORTER LENGTHS.

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**Figure 5-2. View of Crosshairs and Tolerance Areas in Optical Alignment Sight**

**i.** When alignment is complete, all four alignment nuts should be tight.

**j.** Align the retroreflector as follows:

1. Remove the alignment sight at the retroreflector.

2. Attach the 6 in. extension tube and alignment sight to the retroreflector (Figure 5-1). The extension tube is required to square the retroreflector to the projected light beam.

3. Look directly through the alignment sight and check for a centered beam of light from the transceiver.

4. Use the alignment nuts on the retroreflector's air window to center the beam of light onto the frosted field of the alignment sight. Carefully tighten the nuts while maintaining alignment.

5. Recheck the crosshairs by removing the extension tube. The crosshairs should remain centered. If not, readjust the transceiver ball joint.

**k.** Remove the alignment sight and extension tube from the retroreflector.

**l.** Install the end cap and corner cube assembly on the retroreflector.

**m.** Install the weatherproof housings over the transceiver and retroreflector modules.

**n.** Using the HART Communicator, select the EXIT option to leave the check optics mode.

**o.** At the "Return control loop to automatic control" message, return the OPM 2000R to the automatic control loops previously removed and press Enter.

**p.** After waiting 30 minutes for the unit to stabilize, check the calibration. Recalibrate if necessary. Calibration can be checked by inserting the zero jig. If opacity differs from 0.0% by more than ±0.5%, recalibrate per paragraph 6-7.b.

**5-2. <u>OBJECTIVE LENS ADJUSTMENT</u>.** The OPM 2000R is configured at the factory for the user's stack diameter. If readjustment is ever necessary, the transceiver assembly and retroreflector body must be set in a clean environment and at the same distance apart (flange-to-flange) as when installed on the stack. The following steps are performed to focus the objective lens.

**CAUTION**

**Removing covers from the optical assembly or making optical repairs or adjustments in an unsuitable environment can affect the accuracy of the unit. Removal of the electronics housing and optical cover, as well as all repairs and adjustments to the optical assembly, must be performed in a clean, dust-free environment.**

**a.** Enter the check optics mode as follows:

1. Attach the HART Communicator to the 4-20 mA signal line and turn on the device. Refer to paragraph 6-2 for HART Communicator installation information.

2. From the online menu, select DEVICE SETUP.

3. Next, select DIAG/SERVICE from the DEVICE SETUP menu.

4. From the DIAG/SERVICE sub-menu, select CHECK OPTICS.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the CHECK OPTICS procedure may result in undesired equipment performance.**

5. A "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any control loops and press OK to continue. Then, an "About to begin check optics" status message briefly displays.

6. In the next screen, the system prompts you to select the LCW state. Scroll to $V_{STACK}$ and press Enter. The present $V_{STACK}$ value will display. Proceed to the stack. A steady beam of light should be leaving the transceiver.

**b.** Remove the end cap from the retroreflector body.

**c.** Install the alignment sight in the retroreflector body (Figure 5-1).

**d.** Refer to Figure 2-2:

1. Remove electronics housing (14).

2. Remove thumbscrew (2) and optical enclosure cover plate (1).

**e.** Refer to Figure 5-3. Loosen the set screws securing the objective lens.

**f.** Slide the objective lens toward the aperture or away from the aperture.

**g.** During the adjustment, look through the alignment sight at the aperture crosshairs. Stop the adjustment when the crosshairs are in sharp focus and tighten the set screws.

**h.** Remove the alignment sight from the retroreflector body (Figure 5-1).

**i.** Reinstall the end cap assembly to the retroreflector.

**j.** Reinstall optical enclosure cover plate (1, Figure 2-2) and secure with screw (2).

**k.** Use the HART Communicator to check the $V_{STACK}$ and $V_{LAMP}$ voltages, make adjustments as necessary, and exit the check optics mode as follows:

1. When prompted for the next step, select the REFRESH option. Note the current $V_{STACK}$ value.

2. When prompted again for the next step, select $V_{LAMP}$ to display the current $V_{LAMP}$ value.

3. If $V_{STACK}$ and $V_{LAMP}$ are not both 4.0 ±0.1 V, adjust the gain per paragraph 8-3.d.

4. Once the two voltages are 4.0 ±0.1 V, select the EXIT option.

5. At the "Return control loop to automatic control" message, return the OPM 2000R to the automatic control loops previously removed and press Enter.

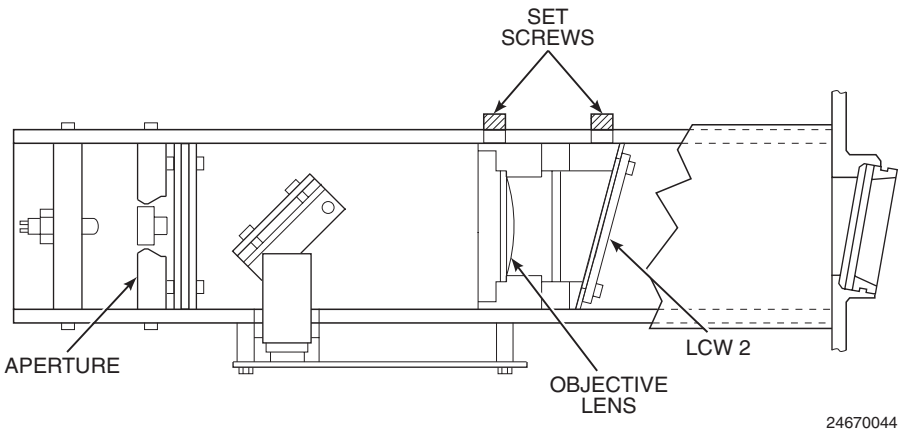



**Figure 5-3. Objective Lens Adjustment**

# SECTION VI. OPERATION

**6-1. OVERVIEW.** The HART Communicator is a hand-held communications interface device. It provides the operator interface to the OPM 2000R. Its 8 line x 21 character liquid crystal display (LCD) and 25 keys are used to view data and to configure and calibrate the unit. A pocket-sized manual is also included with the HART Communicator that details the specific functions of all the keys.

The HART Communicator accomplishes its task using a frequency shift keying (FSK) technique. With the use of FSK, high-frequency digital communication signals are superimposed on the 4-20 mA transmitter current loop. The communicator does not disturb the 4-20 mA signals since no net energy is added to the loop.

To interface with the OPM 2000R, the HART Communicator requires a termination point along the 4-20 mA current loop and a minimum load resistance of 250 ohms between the communicator and the power supply. To simplify the connection procedure, the OPM 2000R provides two banana jacks at each of the transceiver and intelligent electronics sites so the HART Communicator can be used at either location as shown in Figure 6-1.

There is an option to interface the HART Communicator with a personal computer by loading the designated AMS software into the PC and linking the HART Communicator to the PC using the PC interface adapter. The adapter connects to the serial port on the rear panel of the communicator. Refer to the proper HART Communicator documentation for more information.

**6-2. HART COMMUNICATOR SIGNAL LINE CONNECTIONS.** There are two methods of connecting the HART Communicator to the signal line. For applications in which the signal line has a load resistance of 250 ohms or more, refer to method 1. For applications in which the signal line load resistance is less than 250 ohms, refer to method 2.

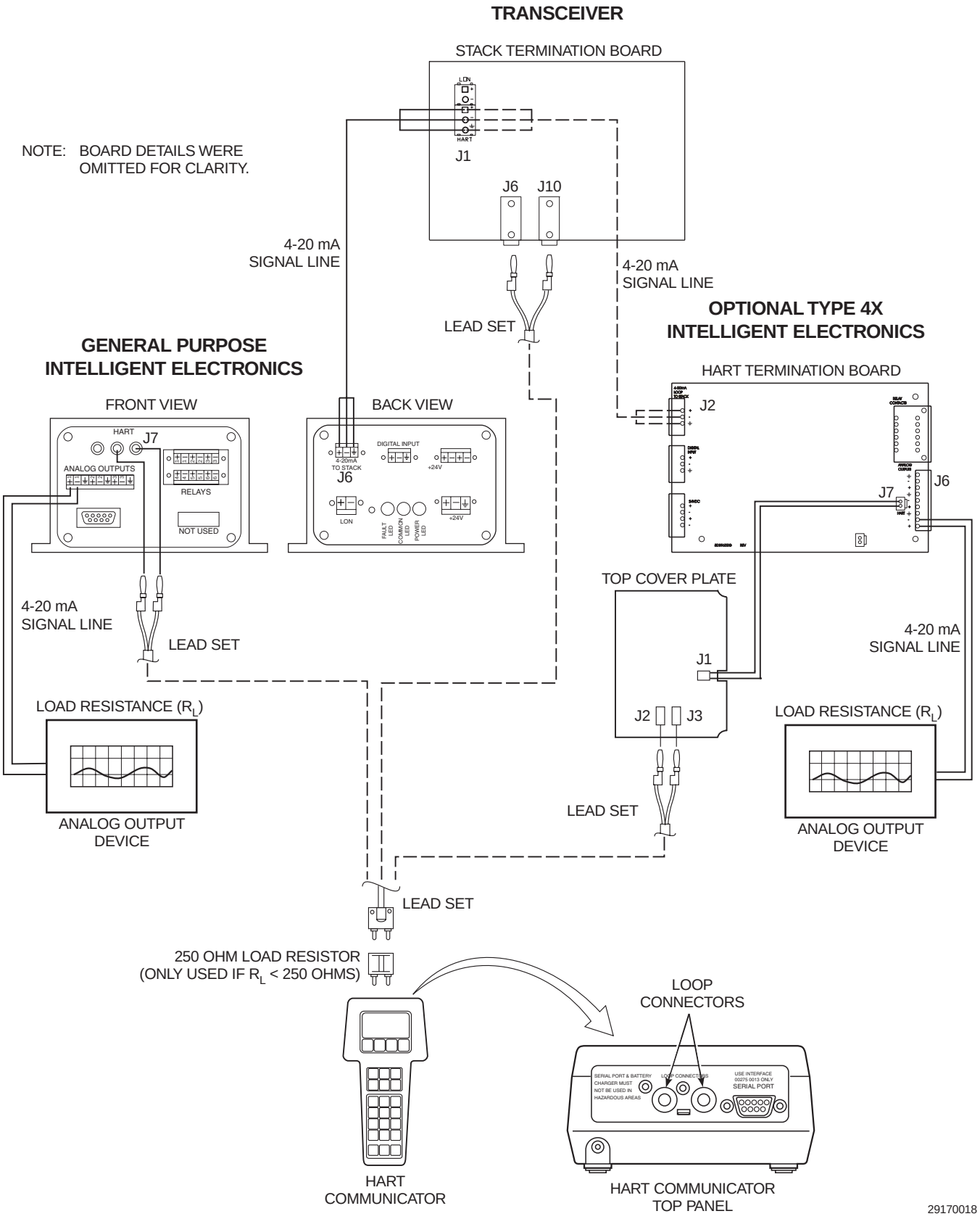



**Figure 6-1. HART Terminal Connections**

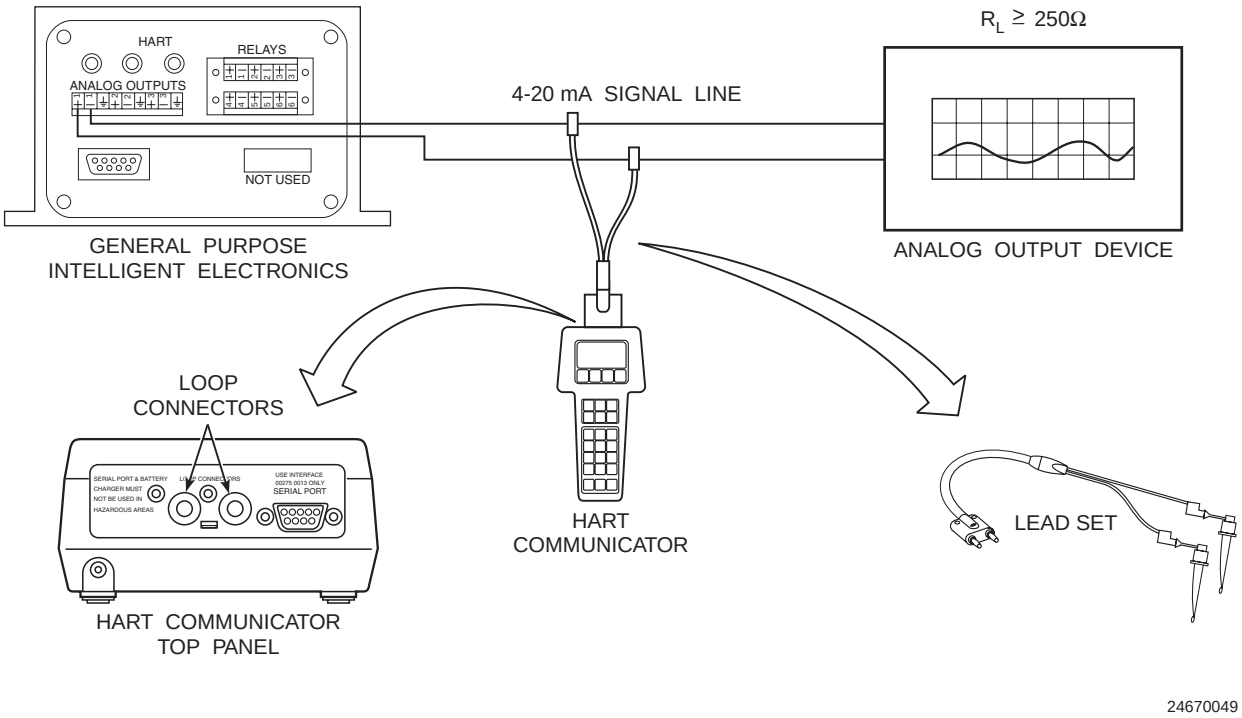



**Figure 6-2. Signal Line Connections, ≥250 Ohms Lead Resistance**

**a. <u>Method 1, for Load Resistance ≥ 250 Ohms</u>.**

**WARNING**

**Explosions can result in death or serious injury. Do not make connections to the HART Communicator's serial port, 4-20 mA signal line, or NiCad recharger jack in an explosive atmosphere.**

1. If attaching the HART Communicator to an OPM 2000R using the banana jacks provided at the stack termination board or the intelligent electronics, refer to Figure 6-1 and the following procedure.

   (a) Connect the supplied lead set to the loop connectors on the HART Communicator top panel.

   (b) Connect the opposite end of the lead set to the banana jacks on either the intelligent electronics or the stack termination board.

2. If attaching the HART Communicator to an OPM 2000R using a wiring termination point in the analog output (AO1) 4-20 mA signal line, refer to Figure 6-2 and the following procedure:

   (a) Connect the supplied lead set to the loop connectors on the HART Communicator top panel.

   (b) Using the banana clips supplied with the lead set, connect the HART Communicator in parallel to the load resistance.

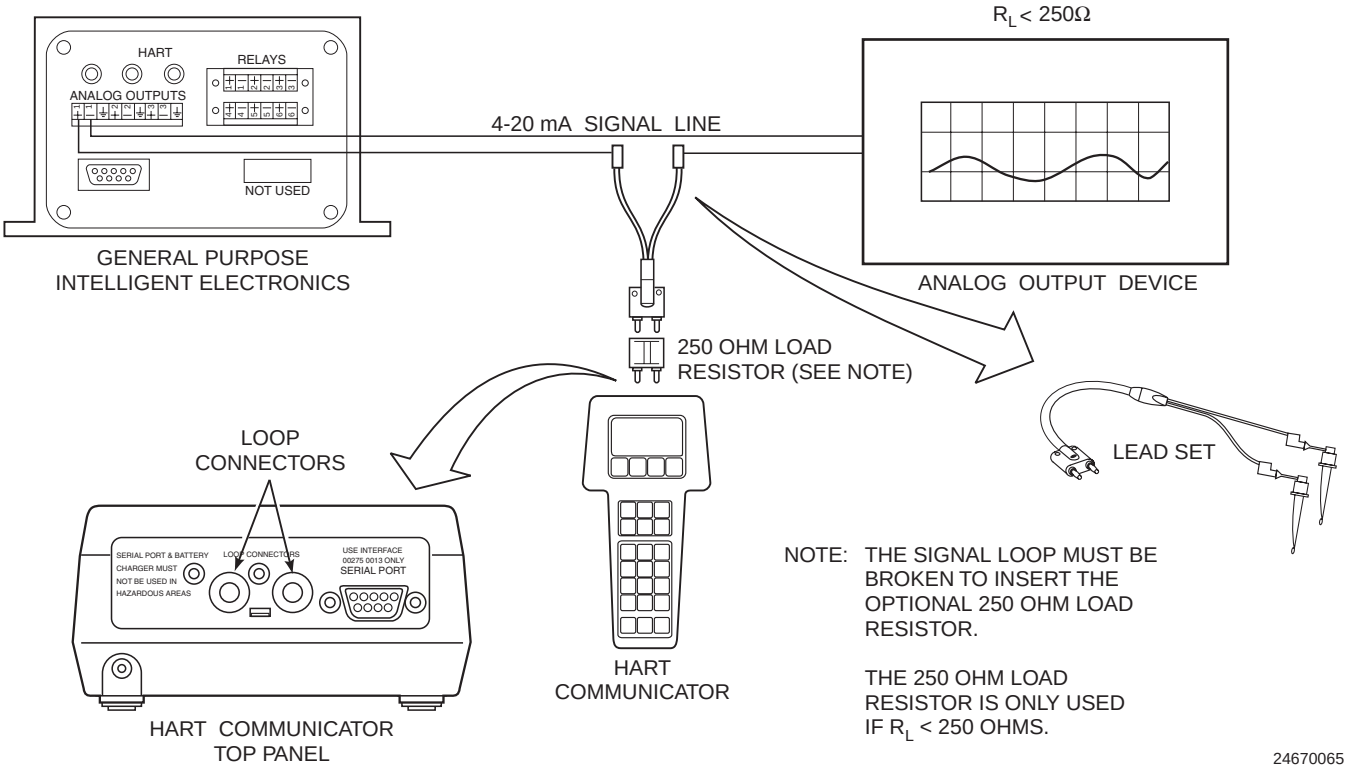



**Figure 6-3. Signal Line Connections, <250 Ohms Lead Resistance**

**b. <u>Method 2, for Load Resistance < 250 Ohms</u>.**

**WARNING**

**Explosions can result in death or serious injury. Do not make connections to the HART Communicator's serial port, 4-20 mA signal line, or NiCad recharger jack in an explosive atmosphere.**

1. If attaching the HART Communicator to an OPM 2000R using the banana jacks provided at the stack termination board or the intelligent electronics, refer to Figure 6-1 and the following procedure:

   (a) Connect a 250 ohm load resistor to the loop connectors on the HART Communicator top panel.

   (b) Connect the supplied lead set to the 250 ohm load resistor and to the banana jacks on either the intelligent electronics or the stack termination board.

2. If attaching the HART Communicator to an OPM 2000R using a wiring termination point in the analog output (AO1) 4-20 mA signal line, refer to Figure 6-3 and the following procedure:

   (a) Connect a 250 ohm load resistor to the loop connectors on the HART Communicator top panel.

   (b) Connect the supplied lead set to the 250 ohm load resistor.

   (c) At a convenient point, break the analog output (AO1) 4-20 mA signal line and, using the banana clips supplied with the lead set, connect the HART Communicator to the 4-20 mA signal line.

**6-3. OFFLINE AND ONLINE OPERATIONS.** The HART Communicator can be operated both offline and online.

**a.** In the online mode, the communicator is connected to the 4-20 mA analog output signal line. The communicator is connected in parallel to the OPM 2000R or in parallel to the 250 ohm load resistor.

**b.** Offline operations are those in which the communicator is not connected to the OPM 2000R. The only offline operation used with the OPM 2000R is interfacing the HART Communicator with a PC. (Refer to the applicable HART documentation regarding HART/PC applications.)

**6-4. HART OPERATOR INTERFACE DESCRIPTION.** The HART Communicator (Figure 6-4) has an 8-line, 21-character liquid crystal display (LCD) and 25 keys that provide communication between you and the OPM 2000R.

**a. LCD Display.** When connected to a HART Communicator, the top line of each online menu displays the model name of the connected device and its tag. In addition, the bottom line of each menu is reserved for the dynamic labels for each software-defined function key (F1 through F4) directly below the display.

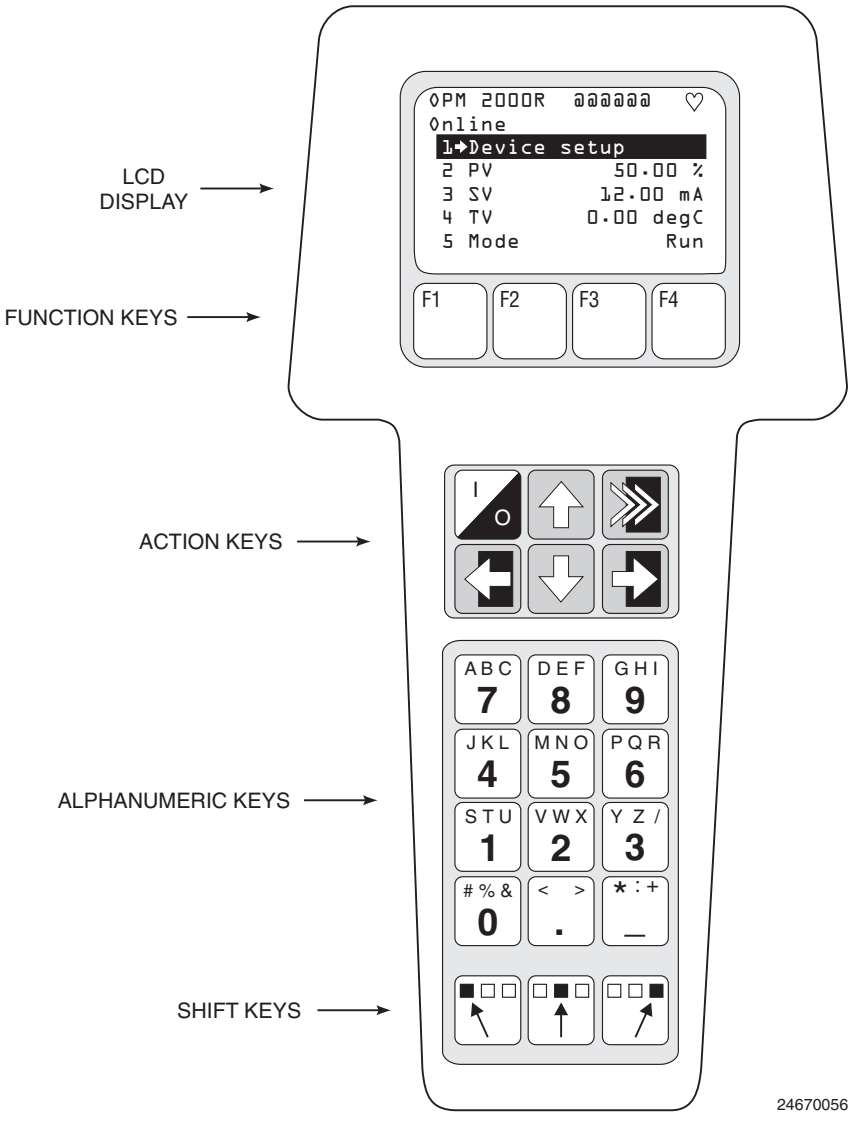



**Figure 6-4. HART Communicator Operator Interface**

**b. Function Keys (F1 through F4).** The function of each key varies depending on the name that displays above it in the last line of the LCD display. Table 6-1 provides the location and purpose of each key.

**c. Action Keys.** The action keys are located just below the function keys on the HART Communicator. Table 6-2 describes the function of each key.

**d. Alphanumeric and Shift Keys.** The alpha-numeric keys (Figure 6-4) can be used to select menu options or enter data.

If you press only the alphanumeric key within an edit menu, only the bold numeric character in the center of the key is selected.

To select the other characters on the key, first press and release the appropriate shift key and then press the alphanumeric key. For example, to select the letter K, first press the second shift key and then press the K key.

**Table 6-1. Function Keys.**

| F1 | F2 | F3 | F4 |
|---|---|---|---|
| **HELP** Accesses online help | **ON/OFF** Activates or deactivates a bit-enumerated binary variable | **ABORT** Terminates current task without saving configuration data | **OK** Acknowledges information on the screen |
| **RETRY** Tries to re-establish communication | **DEL** Deletes current character | **ESC** Leaves a value unchanged | **ENTER** Accepts user-entered data |
| **EXIT** Leaves the current menu | **SEND** Sends configuration data to the device | **QUIT** Terminates a session because of a communication error | **EXIT** Leaves the current menu |
| **YES** Answer to yes/no question | **PGUP** Moves up one help screen | **PGDN** Moves down one help screen | **NO** Answer to yes/no question |
| **ALL** Includes current Hot Key item on Hot Key Menu for all devices | **PREV** Goes to a previous message in a list of messages | **NEXT** Goes to the next message in a list of messages | **ONE** Includes Hot Key item for one device |
| **NEXT** Goes to the next variable in offline edit | **SAVE** Saves information to memory module or data pack | **HOME** Goes to the top menu in the device description | |
| **FILTR** Opens customization menu to sort configurations | **MARK** Toggles marked configuration variables for sending to a field device | **BACK** Goes back to the menu from which HOME was pressed | |
| | **XPAND** Opens detailed configuration information | **EDIT** Edits a variable value | |
| | **CMPRS** Closes detailed configuration information | **ADD** Adds current item to Hot Key Menu | |

**Table 6-2. Action Keys.**

| KEY | FUNCTION |
|---|---|
| **I/O** | Turns the HART Communicator ON and OFF. |
| ⇧ | The up arrow key moves the cursor up through a menu or list of options. An up arrow symbol next to a menu option on the display indicates that you can scroll upward for more options. |
| ⟩⟩⟩ | The hot key provides fast access to your most frequently used tasks. Refer to the HART Communicator manual for more information. |
| ⇦ | The left arrow key moves the cursor to the left in an editable field or returns to a previous menu. A left arrow symbol in the top right-hand corner of the display indicates that you can return to a previous menu. |
| ⇩ | The down arrow key moves the cursor down through a menu or list of options. A down arrow symbol next to a menu option on the display indicates that you can scroll downward for more options. |
| ⇨ | The right arrow key moves the cursor to the right in an editable field or selects a menu option. A right arrow symbol next to a highlighted menu option indicates the option contains more selections. |

**6-5. <u>USING THE HART INTERFACE</u>.** Once the HART Communicator is connected to the OPM 2000R system, turn on the HART Communicator using the I/O key. The first screen that displays is the online menu (Figure 6-5) which has the following menu options: DEVICE SETUP, PV, SV, TV, and MODE.

**NOTE**

**As you set up your OPM 2000R system, record all of your settings for reference on the worksheet provided in Appendix C.**

**a. <u>DEVICE SETUP</u>.** This menu item expands into the menu tree shown in Figure 6-10 at the end of this section. It contains all of the displays and procedures used to monitor and control the OPM 2000R system. Refer to paragraphs 6-6 through 6-10 for more information.

To select a menu option within the DEVICE SETUP menu structure, either press the right arrow action key or use the alphanumeric keypad and press the number that corresponds with the menu option.

**b. <u>PV, SV, and TV</u>.** PV, SV, and TV are standard HART terms for primary value, secondary value, and tertiary value. These menu items are display-only variables that display critical, up-to-date device information such as opacity, stack temperature, transmittance, etc. The information monitored by these three variables are also connected to the three analog outputs.

**c. <u>MODE</u>.** The mode continuously displays system status. The system can be in one of ten modes as described in Table 6-3. These mode indications aid in troubleshooting the system. Refer to Section VII for more information.

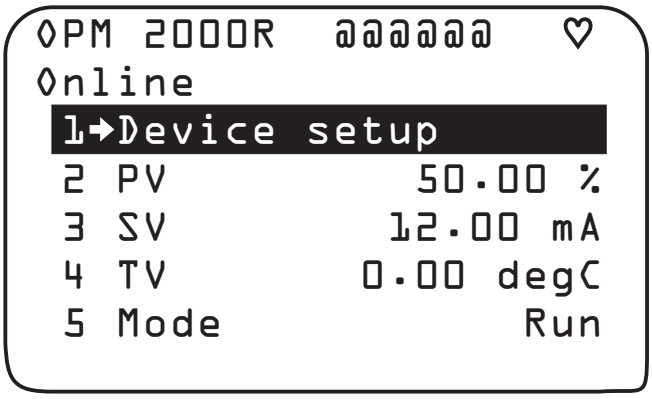



**Figure 6-5. Online Menu**

**Table 6-3. System Status Modes.**

| MODE | DESCRIPTION |
|---|---|
| **RUN** | Normal operating mode. |
| **CAL** | An offline calibration is in progress. |
| **OPTICS CHK** | An optics check is in progress. |
| **FLTR CHK** | A filter check is in progress. |
| **ZSP CHK** | A zero/span check is in progress. |
| **CALF** | The last calibration failed. |
| **COMF** | A communication failure exists between the transceiver and the intelligent electronics. |
| **SYSFLT** | A system fault condition exists, such as a lamp failure, high lamp voltage reading, or blower failure. |
| **CALF&SYSFLT** | The last calibration failed and a system fault exists. |
| **FIXED MA** | A trim DAC procedure or loop test is in progress. |

**Table 6-4. FLD DEVICE VOLTS Sub-menu.**

| MENU ITEM | TYPICAL VALUE | DESCRIPTION |
|---|---|---|
| **$V_{STACK}$ (read-only)** | 3.239 V | Voltage produced when a generated light beam is sent across the stack and reflected back to the transceiver by the retroreflector. |
| **$V_{LAMP}$ (read-only)** | 3.848 V | Voltage produced when a generated light beam is reflected within the transceiver; used to compensate for the effects of an aging bulb, other aging components, and power fluctuations. |
| **$V_{AMB}$ (read-only)** | 0.205 V | Voltage produced from the ambient light coming from the stack. |
| **$V_{DARK}$ (read-only)** | 0.343 V | Voltage produced when the voltage detector is blocked from the light beam and ambient light; used to compensate for any internal light leakage within the transceiver. |
| **Stack Temperature** | N/A | Menu item that further sub-divides into Vad590 and Temp. |
| **Vad590 (read-only)** | 3.000 V | Voltage produced from the temperature of the optical assembly in the transceiver; used to calculate the stack temperature. |
| **Temp (read-only)** | 27 °C | Stack temperature (in °C). The stack temperature is calculated using the following equation:<br>(Vad590 × 100) - 273 = Stack Temperature |

**6-6. <u>PROCESS VARIABLES Menu</u>.** This menu displays the variables critical to the OPM 2000R process, such as the voltages produced by the different light paths in the transceiver and retroreflector. Also, it gives you the opportunity to specify three variables (PV, SV, and TV) to monitor on the online menu.

To access the PROCESS VARIABLES menu, select the DEVICE SETUP menu item from the online menu and select PROCESS VARIABLES. Four menu options are available: FLD DEVICE VOLTS, OUTPUT VARIABLES, VARIABLE MAPPING, and VARIABLE RE-MAP.

**a. <u>FLD DEVICE VOLTS</u>.** This sub-menu displays the current values of four voltages produced by the different light paths taken in each measurement cycle. It also displays the stack temperature and the voltage needed to calculate the stack temperature. To access the FLD DEVICE VOLTS sub-menu, select FLD DEVICE VOLTS from the PROCESS VARIABLES menu. The available menu items are explained in Table 6-4.

The light paths are controlled by the Liquid Crystal Windows (LCWs) shown in Figure 6-6. The LCWs are transparent when ON and translucent when OFF. In the translucent state, light is scattered and effectively blocked. Table 6-5 shows the LCW state for each measured voltage. LCW 2 has five sectors that can be individually controlled during the zero and span checks. See paragraph 6-9.b. During normal operation, all of the sectors are turned ON and OFF at the proper time.

**Table 6-5. LCW States.**

| VOLTAGE | LCW 1 | LCW 2 (Sector 5) | LCW 2 (Sectors 1 - 4) |
|---|---|---|---|
| **$V_{STACK}$** | ON | ON | OFF |
| **$V_{LAMP}$** | ON | OFF | ON |
| **$V_{AMB}$** | OFF | ON | OFF |
| **$V_{DARK}$** | OFF | OFF | OFF |

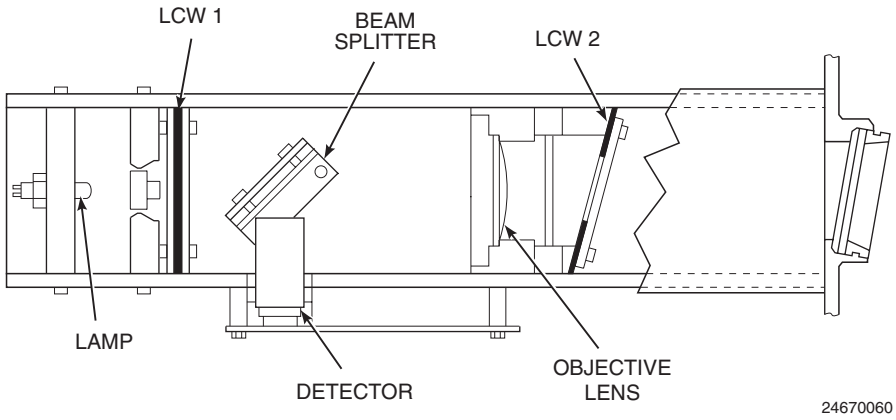



**Figure 6-6. LCW Locations**

**b.** **OUTPUT VARIABLES.** This sub-menu is used to identify the three variables (PV, SV, and TV) that define the analog outputs (AO1, AO2, and AO3). To access this display, select OUTPUT VARIABLES from the PROCESS VARIABLES menu. Selecting a variable on this sub-menu accesses a display listing the four parameters that define each variable as explained in Table 6-6.

**c.** **VARIABLE MAPPING.** This display-only menu item identifies the three variables selected to represent PV, SV, and TV. To access this display, select VARIABLE MAPPING from the PROCESS VARIABLES menu. To exit the display, press Exit.

**Table 6-6. OUTPUT VARIABLES Sub-menu.**

| MENU ITEM | DESCRIPTION | DEFAULT SETTING |
|---|---|---|
| **PV Output Vars** | Displays the four parameters that define PV (analog output 1). | N/A |
| **PV is (read-only)** | Identifies the type of output variable. PV can represent opacity, transmittance, optical density, extinction, or dust concentration. | Opacity |
| **PV Value (read-only)** | Displays the PV value in the appropriate units for the variable selected. | N/A |
| **% Range (read-only)** | Displays the upper range value that corresponds to the full-scale analog output as a percentage of range. This variable is used to scale the analog output. For example, if % RANGE is set to 25%, any variable value greater than or equal to 25% of full range will force the analog output to be 20 mA. Refer to paragraph 6-8.b for more information. | N/A |
| **PV AO (read-only)** | Displays the analog output value in milliamps. | N/A |
| **SV Output Vars (read-only)** | Displays the four parameters that define SV (analog output 2). SV can represent opacity, transmittance, optical density, extinction, dust concentration, temperature, *lx/lt,* or one of the 12 averages detailed in paragraph 6-9.c. | Transmittance |
| **TV Output Vars (read-only)** | Displays the four parameters that define TV (analog output 3). TV can represent opacity, transmittance, optical density, extinction, dust concentration, temperature, *lx/lt,* or one of the 12 averages detailed in paragraph 6-9.c. | Temperature |

**d.** **VARIABLE RE-MAP.** This procedure allows you to select the three variables that represent PV, SV, and TV.

Use the following procedure to change the PV, SV, and TV output variables.

1. Select VARIABLE RE-MAP from the PROCESS VARIABLES menu.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the VARIABLE RE-MAP procedure may result in undesired equipment performance.**

2. Next, a "Pressing OK will change device output. Put loop in manual" message appears. Remove the OPM 2000R from any automatic control loops to avoid undesirable equipment performance and press OK.

**NOTE**

**The MORE option in the scrollable list indicates that additional selections are available on the next screen. However, if you select the MORE option, you cannot return to the selections on the previous screen.**

3. The next screen prompts you to select a PV variable. Select one of the variables from the scrollable list and press Enter.

4. The following screen prompts you to select an SV variable. Select one of the variables from the scrollable list and press Enter.

5. The next screen prompts you to select a TV variable. Select one of the variables from the scrollable list and press Enter.

6. Next, a "Return control loop to automatic control" note appears. Return the OPM 2000R to the automatic control loops previously removed and press Enter.

7. Access the VARIABLE MAPPING display to verify if the variables reflect the latest changes.

**6-7.** **DIAG/SERVICE Menu.** This menu is used to perform diagnostics to troubleshoot and service the OPM 2000R. To access the DIAG/SERVICE menu, select the DEVICE SETUP menu item from the online menu and select DIAG/SERVICE. Seven sub-menus are available: STATUS, OFFLINE CAL, REF. VOLTAGES, TRIM DAC, LOOP TEST, CHECK OPTICS, and FLTR CHK.

**a.** **STATUS.** The menu items in the STATUS sub-menu indicate current instrument status, alarm status, and possible equipment or communication failures. Whenever the status mode on the online menu indicates a CALF, COMF, SYSFLT, or CALF&SYSFLT mode, access the STATUS sub-menu to display the current instrument status and alarm statuses that may indicate a possible equipment or communication failure. All of the menu items displayed will be either ON or OFF.

To access the STATUS sub-menu, select STATUS from the DIAG/SERVICE menu.

Refer to Section VII for more information on how the STATUS menu items are used to troubleshoot the OPM 2000R.

**b.** **OFFLINE CAL.** The OFFLINE CAL menu item provides a procedure to perform an offline calibration. The OPM 2000R is calibrated at the factory per customer data specifications. Only recalibrate the unit in a clean laboratory area, or on a clear stack while using the zero jig option. The resulting voltages are stored in the non-volatile memory of the software chip on the stack LON board in the transceiver.

To calibrate the unit, use the following procedure.

1. If calibrating while the unit is installed on the stack using a zero jig, go to step 2. If calibrating the unit in a clean laboratory, use the following procedure:

   (a) Remove optical assembly (1, Figure 2-1) from the transceiver module per paragraph 8-3.a.1.

   (b) Remove the retroreflector weather housing, turn off power to the retroreflector blower, and remove the retroreflector body (Figure 5-1). Install the weather housing on the retro-reflector module.

(c) Turn off power to the intelligent electronics (Figure 3-1 or Figure 3-5 as appropriate). Tag and remove all cables and wires from the intelligent electronics and remove the unit from its mounting location.

(d) Move optical assembly, retroreflector body, and intelligent electronics to a clean laboratory.

(e) Set up the transceiver and retroreflector in a zero opacity location. Ensure the test setup has the same flange-to-flange distance *(lf)* as on the stack and make sure the transceiver and retroreflector are properly aligned. Refer to Section V for alignment information if necessary.

(f) Connect the LON test cable to communications cable (3, Figure 2-1) and the LON connector on the intelligent electronics.

(g) Connect the transceiver power test cable to power cable (2) and a suitable voltage source.

(h) Connect the HART Communicator to the intelligent electronics and turn on the communicator.

(i) To access the FLD DEVICE VOLTS sub-menu, select DEVICE SETUP from the online menu and select PROCESS VARIABLES. Next, select FLD DEVICE VOLTS. Examine the $V_{STACK}$ and $V_{LAMP}$ variables. Both variables should be between 3.0 and 4.0 V.

(j) If necessary, remove electronics housing (14, Figure 2-2) to adjust the gain potentiometer on the detector amplifier board so both the $V_{STACK}$ and $V_{LAMP}$ values are between 3.0 and 4.0 V. For best performance, try to adjust $V_{STACK}$ and $V_{LAMP}$ to 4.0 ±0.1 V. Refer to paragraph 8-3.d for the procedure to adjust the gain.

(k) Install electronics housing (14).

(l) Make sure the laboratory is dimly lit before performing the offline calibration procedure.

2. If not attached, connect the HART Communicator at the stack termination board or the intelligent electronics per paragraph 6-2 and turn on the communicator.

3. If using a zero jig for this offline calibration, insert the jig per paragraphs 6-7.g.2(c) through (e).

4. Select OFFLINE CAL from the DIAG/ SERVICE menu.

5. The first screen prompts you to press the pushbutton light to begin the calibration. Press the CAL/CHECK backlit button (Figure 6-7) on the front mounting plate of the transceiver, and the system automatically begins to measure 0% opacity and record 0% opacity reference volts.

6. The next screen informs you to wait while the system performs a 0% calibration. Once 0% calibration is complete, the system instructs you to turn the corner cube around and press the pushbutton light to begin 100% calibration. The back of the corner cube is a black reflector that simulates 100% opacity. If the zero jig is in use, insert the black paddle that shipped with the zero jig instead of using the back of the corner cube. Press the CAL/CHECK backlit pushbutton on the front mounting panel of the transceiver.

7. The next screen informs you to wait while the system performs a 100% calibration. When 100% calibration is complete, the system instructs you to turn the corner cube back around and press the pushbutton light to continue. If the zero jig is in use, remove the black paddle from the zero jig instead of turning the corner cube around. Press the CAL/CHECK backlit pushbutton on the front mounting panel of the transceiver.

8. Next, the screen displays the current PV value and Optical Correction Factor (OCRF) and gives you three options: REFRESH, CHANGE OCRF, and END CALIBRATION.

   The OCRF provides a correction factor for an offline calibration. Normally, this value should be left at 0.00. If certified neutral density filters (NDFs) are available, they can be inserted into the light path to verify the calibration. The OCRF can then be adjusted to force the unit to better match the filter values. The OCRF is a percent of reading

correction and is limited to ±10%. This factor normally is not required because the OPM 2000R is capable of measuring well within 2% opacity.

The following example demonstrates the use of the OCRF.

**NOTE**

**In these examples, *lx/lt* equals 1. If *lx/t* does not equal 1, correct the opacity reading for *lx/lt*. Refer to paragraph 6-7.g.4. Then, adjust the OCRF if necessary.**

The certified values for three different NDFs are the following:

NDF #1 = 8.1%
NDF #2 = 20.5%
NDF #3 = 37.9%

During an offline calibration of the OPM 2000R, the three NDFs have the following opacity readings while the OCRF equals 0:

NDF #1 = 8.5%
NDF #2 = 22.5%
NDF #3 = 41.0%

Since the opacity readings of the three NDFs are not the same as their certified values, the OCRF should be changed to make the opacity reading more accurate. When the OCRF is changed to 2, the three NDFs have the following opacity readings:

NDF #1 = 8.65%
NDF #2 = 22.9%
NDF #3 = 41.6%

When the OCRF is changed to -10, the three NDFs have the following opacity readings:

NDF #1 = 7.7%
NDF #2 = 20.5%
NDF #3 = 37.8%

In this example, changing the OCRF value to -10 is the best setting because it changes the opacity readings of all three of the NDFs closest to their certified values—NDFs 2 and 3 in particular.

9. To change the OCRF, select the CHANGE OCRF menu item, change the OCRF to a value between -10.0 and +10.0, and press Enter.

10. Select the REFRESH menu item to update the PV and OCRF values.

11. Select END CALIBRATION to return to the DIAG/SERVICE menu.

12. Remove the zero jig if it is in use.

**c. <u>REF. VOLTAGES</u>.** REF. VOLTAGES sub-menu displays voltages that were measured during the last offline calibration at 0% opacity and at 100% opacity. It also displays the date and time of the last offline calibration. The current voltages can be compared to the reference values to determine how much they have changed since the last calibration. The opacity monitor formulas compensate for changes in ambient light and the lamp intensity. Table 6-7 identifies the reference voltages and provides typical values for each. For definitions of the voltage values refer to Table 6-4.

**Table 6-7. REF. VOLTAGES Sub-menu.**

| MENU ITEM | TYPICAL VALUES | DESCRIPTION |
|---|---|---|
| **CalDate (read-only)** | 10/21/97 | Date of the last calibration (DD/MM/YY). This parameter automatically updates upon calibration. |
| **CalTime (read-only)** | 02:00 | Time of day of the last calibration (HH:MM). This parameter automatically updates upon calibration. |
| **$V_{STACK}0$ (read-only)** | 3.972 | Voltage value at 0% opacity. |
| **$V_{LAMP}0$ (read-only)** | 3.691 | |
| **$V_{AMB}0$ (read-only)** | 0.399 | |
| **$V_{DARK}0$ (read-only)** | 0.186 | |
| **$V_{STACK}1$ (read-only)** | 1.207 | Voltage value at 100% opacity. |
| **$V_{LAMP}1$ (read-only)** | 3.694 | |
| **$V_{AMB}1$ (read-only)** | 0.187 | |
| **$V_{DARK}1$ (read-only)** | 0.184 | |
| **OCRF (read-only)** | 0.000 | Correction factor for an offline calibration. |

**d.** **TRIM DAC.** The TRIM DAC procedure is used to calibrate the PV (AO1) 4-20 mA signal loop by referencing a high and low count. The PV needs to be trimmed because it uses an integrated circuit to control AO1 that is different than the circuits in SV and TV. The digital information needed to set the analog output correctly varies between integrated circuits. Therefore, to make the integrated circuit accurate, the software needs the digital information collected by trimming the analog output. This diagnostic procedure helps to maintain optimum accuracy and efficiency when communicating with other devices.

In the TRIM DAC procedure, the OPM 2000R is placed in the fixed mA mode in which the digital-to-analog converter outputs a specified milliamp signal, such as 4 mA. By attaching a reference meter to the analog output connections, you can view what the instrument is actually outputting, which may not be 4 mA. The TRIM DAC procedure uses the reference meter value to calibrate the digital-to-analog converter to ensure it outputs 4 mA. Use the following procedure to calibrate the analog outputs:

1. To access the TRIM DAC procedure, select TRIM DAC from the DIAG/SERVICE menu.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the TRIM DAC procedure may result in undesired equipment performance.**

2. Next, a "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any automatic control loops to avoid undesirable equipment performance and press Enter.

3. The next screen directs you to connect a reference meter. Connect an ammeter to the analog output connections (Figure 4-10 or Figure 4-11 as appropriate) on the intelligent electronics and press Enter.

4. Next, the screen prompts you to enter the meter value. Observe the value displayed on the reference meter, enter that value, and press Enter.

5. Next, the screen prompts you to enter the meter value. Observe the value displayed on the reference meter, enter that value, and press Enter.

6. When the "Returning fld device to original output" message displays, remove the reference meter from the analog output connections and press Enter.

7. Next, a "Loop may be returned to automatic control" note appears. Return the OPM 2000R to the automatic control loops previously removed and press Enter. If you were to repeat the TRIM DAC procedure, the values that display on the reference meter will match the output of the digital-to-analog converter.

**e.** **LOOP TEST.** The loop test is a diagnostic procedure that allows you to apply a specific current to the 4-20 signal loop to verify that the analog output is connected correctly. To access this sub-menu, select LOOP TEST from the DIAG/SERVICE menu.

1. To verify the current in analog output 1, select LOOP TEST PV from the LOOP TEST sub-menu.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing a loop test may result in undesired equipment performance.**

2. Next, a "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any automatic control loops to avoid undesirable equipment performance. At this time, also install a reference meter to analog output 1 that will register the signal current. To continue the procedure, press Enter.

3. The next screen prompts you either to select a current or to end the test. Choose 4 mA, 20 mA, or OTHER, which gives you the opportunity to enter a different value.

4. Once you make your selection, check the reference meter. If the reference meter value does not match the selected value, you must check your connections. If the values match, analog output 1 is connected correctly.

5. Select END to leave the LOOP TEST procedure.

6. Next, a "Loop may be returned to automatic control" note appears. Return the OPM 2000R to the automatic control loops previously removed, disconnect the reference meter, and press Enter.

7. To verify the analog output 2 or 3, repeat steps 1 through 6 for LOOP TEST SV or LOOP TEST TV, respectively.

**f.** **CHECK OPTICS.** Refer to Section V for the complete CHECK OPTICS procedure.

**g.** **FLTR CHK.** The menu items in the FLTR CHK sub-menu are used to verify the calibration validity of the OPM 2000R using a zero jig and neutral density filters (NDFs). A set of three different NDFs are used multiple times to comply with the EPA Filter Check Method 203 Audit. Typically, this procedure takes less than one hour. NDFs placed in the zero jig will display NDF values corrected for the pathlength correction ratio (OPLR)—referred to as the *lx/lt* ratio in the OPM 2000R. The values will be in the units configured for PV. These measurements are stored by the OPM 2000R and recorded using a data recorder connected to analog output 1. To access this sub-menu, select FLTR CHK from the DIAG/SERVICE menu. Refer to Table 6-8 for descriptions of the available menu items.

**Table 6-8. FLTR CHK Sub-menu.**

| MENU ITEM | DESCRIPTION |
|---|---|
| **Filter Check (method)** | Provides the procedure to check the NDFs to comply with the EPA Filter Check Method 203 Audit. |
| **Fltr Chk Values (method)** | Provides the procedure to display each neutral density filter value, in terms of PV, by selecting the filter number. It also displays time (HH:MM) the value was taken. |
| **Erase Fltr Values (method)** | Provides the procedure to erase test filter data currently stored by the OPM 2000R. The old filter data is usually erased before starting a new filter check. |

1. Use the following procedure to erase test filter data currently stored by the OPM 2000R:

**NOTE**

**If the stored filter values are erased before starting the FILTER CHECK procedure, the procedure will begin at filter 1. If the stored filter values are not erased before starting the FILTER CHECK procedure, the procedure will begin where it previously ended.**

(a) Select ERASE FLTR VALUES from the FLTR CHK sub-menu.

(b) Next, an "About to erase filter values" message appears. Press Enter to clear all values of previous filter checks or press Abort to exit from the screen without erasing the values.

2. Perform the filter check procedure as follows:

(a) Select FILTER CHECK from the FLTR CHK sub-menu.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the FILTER CHK procedure may result in undesired equipment performance.**

(b) Next, a "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any automatic control loops to avoid undesirable equipment performance and press Enter.

(c) The next screen displays an "About to begin filter check" message. At this time, remove the window access plate from the transceiver optical assembly (Figure 6-7).

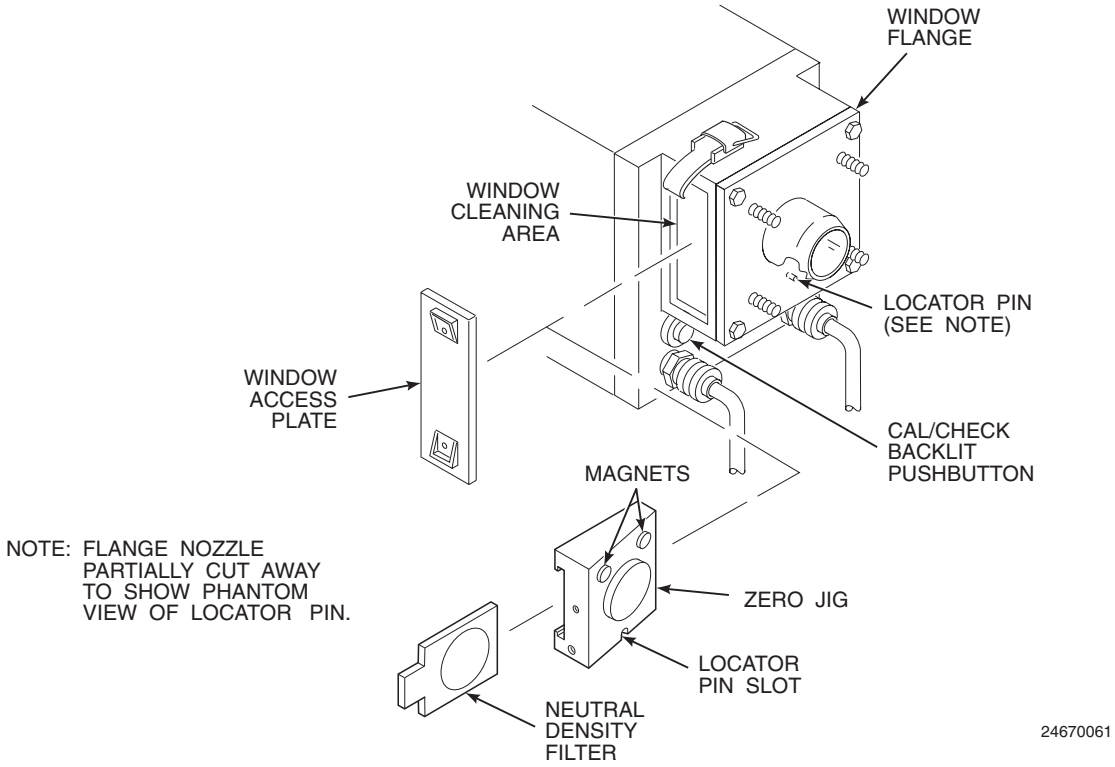



**Figure 6-7. Zero Jig and EPA Filter Placement**

**NOTE**

**A zero jig is specific to the transceiver to which it has been calibrated. Check that the serial number of the zero jig is the same as the serial number of the transceiver.**

**The zero jig requires periodic calibration (typically once per year). Refer to paragraph 8-4 for the zero jig calibration procedure.**

(d) Remove the keepers from the zero jig magnets and place the zero jig through the window cleaning area. Slide the jig on the window flange and onto the locating pin.

(e) Slightly rotate the jig back and forth until the 2 in. (50.8 mm) diameter raised section falls into place. The locator pin and the two permanent magnets hold the jig in position.

(f) Insert neutral density filter 1.

(g) Press Enter on the HART Communicator.

(h) The next screen prompts you to press the pushbutton light to begin reading filter 1. Press the CAL/CHECK backlit button on the front mounting plate of the transceiver.

(i) The following screen informs you to please wait (approximately five seconds) while the system is reading the filter.

(j) At the prompt to begin reading filter 2, remove filter 1, and insert filter 2.

(k) Repeat steps (g) through (j) for the remaining filters.

(l) If you do not wish to check all 30 filters, press Abort to exit the FILTER CHK procedure.

(m) At this time, remove the neutral density filter and zero jig from the transceiver (Figure 6-7).

**CAUTION**

**The zero jig is a sensitive, calibrated instrument. Store the jig in its protective case when not in use. Failure to properly store the jig can lead to damage or an out-of-calibration condition.**

(n) Install the keepers on the zero jig magnets and return the jig to its protective case.

(o) Install the window access plate.

(p) When the "Loop may be returned to automatic control" note appears, return the OPM 2000R to the automatic control loops previously removed and press Enter.

3. Use the following procedure to view the filter check values:

   (a) Select FLTR CHK VALUES from the FLTR CHECK sub-menu.

   (b) The next screen prompts you to select a filter. Enter the number of the filter (1 through 30) you wish to view and press Enter.

   (c) The following screen displays the filter number; the filter value, in terms of PV; and the time the filter was checked. To view another filter, select the NEW FILTER option. To exit the procedure, select EXIT.

4. The OPM 2000R adjusts all readings for the *lx/lt* ratio, including those taken with an NDF. The NDF-certified opacity values are based on an *lx/lt* ratio of 1.0. If the *lx/lt* ratio at your site is not equal to 1.0, an adjustment must be applied to the given NDF-certified opacity value that will yield the correct expected value for your specific site.

   To determine the correct expected opacity value at your site, use the following procedure:

   (a) Convert the NDF-certified opacity value to the equivalent optical density (OD) value using the table in Appendix A.

   (b) Multiply the OD value by the *lx/lt* ratio to get an expected OD value.

   (c) Convert the expected OD value back to an (expected) opacity value using the table in Appendix A.

   The equation for the relationship is as follows:

**expected NDF OD value = certified OD value * *lx/lt* ratio**

**Example 1:**
*lx/lt* ratio = 0.8
certified NDF opacity value = 36.9%
certified OD value = 0.2000 (from Appendix A)
expected NDF OD value = 0.2 * 0.8 = 0.16
expected NDF opacity value = 30.8% (from Appendix A)

**Example 2:**
*lx/lt* ratio = 0.8
certified NDF opacity value = 87.4%
certified OD value = 0.9000 (from Appendix A)
expected NDF OD value = 0.9 * 0.8 = 0.72
expected NDF opacity value = 80.9% (from Appendix A)

**Example 3:**
*lx/lt* ratio = 3.0
certified NDF opacity value = 36.9%
certified OD value = 0.2000 (from Appendix A)
expected NDF OD value = 0.2 * 3.0 = 0.6
expected NDF opacity value = 74.9% (from Appendix A)

**6-8.** **BASIC SETUP MENU.** This menu is used to view and configure basic system requirements. To access the BASIC SETUP menu, select the DEVICE SETUP menu item from the online menu and select BASIC SETUP. Four sub-menus are available: SETUP CLOCK, RANGE VALUES, LX/LT, and DEVICE INFO.

**a.** **SETUP CLOCK.** This sub-menu displays the real-date and real-time and provides a procedure to reset both. To access the SETUP CLOCK sub-menu, select SETUP CLOCK from the BASIC SETUP menu. The menu items available are explained in Table 6-9.

Use the following procedure to change the date and time:

1. From the BASIC SETUP sub-menu, Select CLOCK SETUP.

2. The next three screens will prompt you to enter the current date in month, day, and year, respectively. After typing each entry in the highlighted area, press Enter.

3. The next three screens will prompt you to enter the current time in hours, minutes, and seconds, respectively. After typing each entry in the highlighted area, press Enter.

4. The system then returns to the SETUP CLOCK sub-menu. Verify that the read-only displays in the sub-menu reflect the latest changes.

**Table 6-9. SETUP CLOCK Sub-menu.**

| MENU ITEM | TYPICAL VALUE | DESCRIPTION |
|---|---|---|
| **Date (read-only)** | 09/30/97 | Displays the current date (in MM/DD/YY). The date is maintained by the real-time clock chip on the HART daughter PC board. A battery on the board backs up the real-time clock in the event of a power failure. |
| **Time (read-only)** | 09:30:27 | Displays the current time (in HH:MM:SS). The time is maintained by the real-time clock chip on the HART daughter PC board. A battery on the board backs up the real-time clock in the event of a power failure. |
| **Clock Setup (method)** | N/A | Provides the procedure to reset the date and time of the internal clock. |

**Table 6-10. PV, SV, and TV RANGE VALUES Sub-menu.**

| MENU ITEM | DESCRIPTION |
|---|---|
| **Select PV Range** | Contains the following three parameters that define the PV range. |
| **URV (read-only)** | Displays the upper range value for the selected variable as a percentage of the analog output. A typical value for this variable is 100.00%. The URV can be modified using the PV RANGE SETUP method. |
| **LRV (read-only)** | Displays the lower range value for the selected variable as a percentage of the analog output. A typical value for this variable is 0.00%. This parameter cannot be modified. |
| **PV Range Setup (method)** | Provides the procedure to change the URV of the selected variable. |
| **Select SV Range** | Refer to the Select PV Range menu item. |
| **Select TV Range** | Refer to the Select PV Range menu item. |

**b.** **RANGE VALUES.** The RANGE VALUES sub-menu allows you to set up the ranges for the user-selected PV, SV, and TV variables (analog outputs 1, 2, and 3). To access this sub-menu, select RANGE VALUES from the BASIC SETUP menu. The menu items are SELECT PV RANGE, SELECT SV RANGE, and SELECT TV RANGE. The menu items for this sub-menu are explained in Table 6-10.

Use the following procedure to change the URV for the PV range:

1. From the SELECT PV RANGE sub-menu, select PV RANGE SETUP.

**CAUTION**

**Failure to remove the OPM 2000R from automatic control loops prior to performing the URV procedure may result in undesired equipment performance.**

2. Next, a "Loop should be removed from automatic control" warning appears. Remove the OPM 2000R from any automatic control loops to avoid undesirable equipment performance and press Enter.

3. The next screen prompts you to enter a new upper range value for analog output 1 (PV). Type the value in the highlighted area and press Enter. A typical value for this variable is 100.00% of the analog output.

4. A "Saving range values" message displays while the system updates.

5. Next, a "Loop may be returned to automatic control" note appears. Return the OPM 2000R to the automatic control loops previously removed and press Enter. Verify that the read-only URV menu item reflects the change.

6. Repeat steps 1 through 5 for the SV and TV URV values.

**NOTE**

**If any of the three HART variables (PS, SV, or TV) have the same process variable (i.e., opacity, transmittance, average 1, etc.), setting the URV of one analog output will affect the URV of each analog output whose corresponding HART variable has been assigned the same process variable. For example, if SV and TV are both assigned the process variable of opacity, then setting the URV of analog output 2 (SV) to 50% will automatically set the URV of analog output 3 (TV) to 50%.**

**c.** **LX/LT.** *lx/lt* is the ratio of the inside diameter at the top of the stack to the inside diameter of the stack where the instrument is located. See Figure 6-8. If the ratio is greater than 1.0, the exit opacity will be greater than the opacity at the instrument location. The OPM 2000R uses this correction factor to calculate the stack exit opacity. It is not practical to have an *lx/lt* factor much greater than 2.0 because the error of the instrument increases as *lx/lt* becomes greater.

The LX/LT sub-menu allows you to view and configure the *lx/lt* ratio. The LX/LT menu item is a read-only display of the current *lx/lt* value. Its default setting is 1.00. This value can be changed using the LX/LT SETUP menu item.

Use the following procedure to change the *lx/lt* variable:

1. From the LX/LT sub-menu, select LX/LT SETUP.

2. The next screen prompts you for the *lx/lt* variable. Calculate the ratio to three decimal places by dividing the inside diameter of the top of the stack (*lx*) by the inside diameter of the stack at the instrument (*lt*). Type the new value in the highlighted area and press Enter.

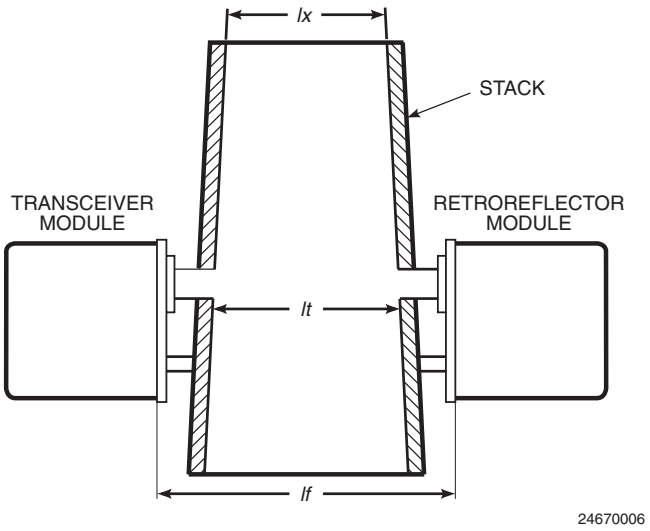



**Figure 6-8. *lx* and *lt* Stack Dimensions**

**Table 6-11. DEVICE INFO Sub-menu.**

| MENU ITEM | DESCRIPTION |
|---|---|
| **Dev id (read-only)** | Identifies the device used with the HART Communicator. The device ID also appears at the top of each screen in the HART Communicator. |
| **Descriptor (read, write)** | Provides a 16-character entry to convey user information. |
| **Tag (read, write)** | Provides an 8-character entry to convey user information. Appears on the top line of every HART display next to the device ID. |
| **Message (read, write)** | Provides a 32-character entry to convey user information. |

3. A "Saving Lx/Lt" message displays while the system updates. Once the value is saved, the system returns to the LX/LT sub-menu. Verify that the read-only Lx/Lt display reflects the change.

**d.** **DEVICE INFO.** This sub-menu allows you to program descriptive or pertinent user information. To access this sub-menu, select DEVICE INFO from the BASIC SETUP menu. The menu items for this sub-menu are explained in Table 6-11.

Use the following procedure to enter a descriptor, tag, or message:

1. To add descriptive information, select DESCRIPTOR, TAG, or MESSAGE from the DEVICE INFO sub-menu. Refer to Table 6-11 for an explanation of each parameter type.

2. The next screen prompts you to enter the descriptive information. Type the entry in the highlighted area and press Enter.

3. The system exits to the DEVICE INFO sub-menu. Verify that the parameter you modified reflects the latest changes.

**6-9. DETAILED SETUP MENU.** The DETAILED SETUP menu is used to configure the OPM 2000R for specific applications. To access the DETAILED SETUP menu, select the DEVICE SETUP menu item from the online menu and then select DETAILED SETUP. Five sub-menus are available: RELAY CONFIG, ZERO/SPAN CHECK, AVERAGES, ALARMS, and DUST SETUP.

**a. RELAY CONFIG.** The RELAY CONFIG sub-menu allows you to configure the relays to energize upon certain alarm or status conditions. It also allows you to view the currently selected trigger signals. To access this sub-menu, select RELAY CONFIG from the DETAILED SETUP menu. The menu items in the sub-menu are explained in Table 6-12.

**NOTE**

**Relays 1 through 5 are normally open. Relay 6 is normally closed.**

To change a default relay output setting, use the following procedure:

1. From the RELAY CONFIG menu, select the RELAY CONFIG menu item.

2. The next screen prompts you to select a relay or exit. Scroll through the list, select a relay, and press Enter.

3. At the next prompt, select one of the signal variables from the scrollable list and press Enter. Note that no two relays can have the same trigger signal.

4. The display will then prompt you to configure another relay or exit the procedure. To configure another relay, repeat steps 2 through 4. When finished, press Exit to return to the RELAY CONFIG sub-menu. Verify that the settings reflect the latest changes by accessing the read-only displays in the sub-menu.

**Table 6-12. RELAY CONFIG Sub-menu.**

| MENU ITEM | POSSIBLE VARIABLES | DESCRIPTION | DEFAULT SETTING |
|---|---|---|---|
| **Relay Config (method)** | N/A | Provides the relay configuration procedure by selecting the variable that triggers each relay. | N/A |
| **Relay 1 (read-only)** | Off<br>Sysflt (System Fault)<br>Span (Span Check)<br>Zero (Zero Check)<br>Flt Chk (Filter Check)<br>Alarm 1<br>Alarm 2<br>On | Displays the currently selected variable for relay 1. | Alarm 1 |
| **Relay 2 (read-only)** | Same as Relay 1 | Displays the currently selected variable for relay 2. | Alarm 2 |
| **Relay 3 (read-only)** | Same as Relay 1 | Displays the currently selected variable for relay 3. | Fltr Chk |
| **Relay 4 (read-only)** | Same as Relay 1 | Displays the currently selected variable for relay 4. | Zero Chk |
| **Relay-5 (read-only)** | Same as Relay 1 | Displays the currently selected variable for relay 5. | Span Chk |
| **Relay-6 (read-only)** | Same as Relay 1 | Displays the currently selected variable for relay 6. | Sysflt |

**b. <u>ZERO/SPAN CHECK</u>.** The ZERO/SPAN CHECK sub-menu allows you to periodically verify the operation of the unit. Zero and span checks are required by EPA performance specification 1, section 5.1.5, as repeated below:

"5.1.5 Simulated Zero and Upscale Calibration System. Each analyzer must include a zero (or no greater than 10%) opacity and an upscale opacity value for the purpose of performing periodic checks of the transmissometer calibration while on an operating stack or duct. This calibration system will provide, as a minimum, a system check of the analyzer internal optics and all electronic circuitry including the lamp and photodetector assembly."

The OPM 2000R uses a sectored Liquid Crystal Window (LCW) to simulate an intermediate zero and upscale calibration check value. The individual sectors are identified in Figure 6-9.

The ZERO/SPAN CHECK sub-menu allows you to view and configure the zero and span check parameters. To access this sub-menu, select ZERO/SPAN CHECK from the DETAILED SETUP menu. Table 6-13 explains the ZERO/SPAN menu items.

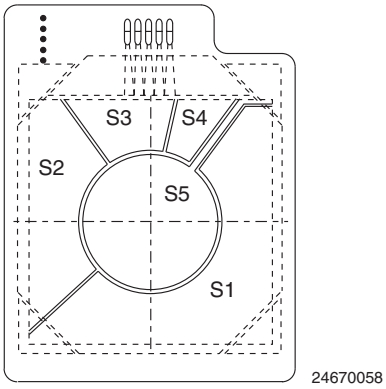



**Figure 6-9. Sectored LCW2**

The typical values displayed in Table 6-13 exemplify a zero/span check that is performed once a day at 2:00 a.m. SPAN VAL will assume the span check value of 23.45% opacity for six minutes. The zero check value will then be output for the next six minutes. If using the default relay setup described in Table 6-12, relay 5 is energized during the span check, and relay 4 is energized during the zero check. This function is enabled when the blower motors are running. Any fault condition will disable this function.

**Table 6-13. ZERO/SPAN CHECK Sub-menu.**

| MENU ITEM | POSSIBLE VARIABLES | TYPICAL VALUE | DESCRIPTION | DEFAULT SETTING |
|---|---|---|---|---|
| **Zero Val (read-only)** | N/A | 6.22% | Displays the analog output value as a percentage of opacity during the last zero check. | N/A |
| **Zero Fltr (read, write)** | S0 through S15 (Refer to Table 6-14 for filter descriptions.) | S14 | Displays and selects the LCW sectors that determine the nominal opacity value for zero check. To change the variable, select ZERO FLTR and follow the instructions on the screen. | S0 |
| **Span Val (read-only)** | N/A | 23.45% | Displays the analog output value as a percentage of opacity during the last span check. | N/A |
| **Span Fltr (read, write)** | S0 through S15 (Refer to Table 6-14 for filter descriptions.) | S12 | Displays and selects the LCW sectors that determine the nominal opacity value for span check. To change the variable, select SPAN FLTR and follow the instructions on the screen. | S0 |
| **Period (read-only)** | value within the 00:00 to 24:00 hour range | 24:00 | Indicates the length of time between check cycles (in HH:MM). | 00:00 |
| **Start (read-only)** | value within the 00:00 to 24:00 hour range | 02:00 | Indicates the time of day the check cycle will begin (in HH:MM). | 00:00 |
| **Zero Dur (read-only)** | value within the 00:00 to 10:00 minute range | 6.00 | Indicates the length of the zero check cycle (in MM:SS). | 00:00 |
| **Span Dur (read-only)** | value within the 00:00 to 10:00 minute range | 6:00 | Indicates the length of the span check cycle (in MM:SS). | 00:00 |
| **Zero/Span Config (method)** | N/A | N/A | Provides the procedure to set the parameters for the zero/span check. | N/A |

The user-required span and zero check values determine which sectors to select. Table 6-14 shows the on/off status of the sectors with each filter check value. All values listed in Table 6-14 are nominal. What is important is that the span check and the zero check values remain consistent from day to day.

To configure the zero/span check, use the following procedure:

1. From the ZERO/SPAN CHECK sub-menu, select ZERO/SPAN CONFIG.

2. The following two screens will direct you to enter the zero/span period in hours and minutes, respectively. After typing each entry in the highlighted area, press Enter.

3. The next two screens will direct you to enter the zero/span start time in hours and minutes, respectively. After typing each entry in the highlighted area, press Enter.

4. The following two screens will prompt you to enter the zero duration in minutes and seconds, respectively, After typing each entry in the highlighted area, press Enter.

5. The next two screens will prompt you to enter the span duration in minutes and seconds, respectively. After typing each entry in the highlighted area, press Enter.

6. At the next screen prompt, select the zero filter from the scrollable list and press Enter.

7. In the following screen, select the span filter from the scrollable list and press Enter.

8. Next, a "Writing zero/span configuration" message appears as the system updates. After configuring the zero/span check, the system returns to the ZERO/SPAN CHECK sub-menu. Verify that the settings reflect the latest changes by viewing the read-only displays in the sub-menu.

**c.** **AVERAGES.** This sub-menu allows you to configure up to two averages of opacity, transmittance, optical density, extinction, dust concentration, or none (no variable specified). For each variable, a time period is specified and the average is calculated from the number of measurements taken during that time period. To access this sub-menu, select AVERAGES from the DETAILED SETUP menu. Table 6-15 explains the menu items in the AVERAGES sub-menu.

**Table 6-14. LCW Sector Status.**

| FILTER VALUE | LCW SECTOR 1 | 2 | 3 | 4 | NOMINAL OPACITY | NOMINAL TRANSMIT-TANCE | NOMINAL OPTICAL DENSITY/ EXTINCTION |
|---|---|---|---|---|---|---|---|
| S0 | OFF | OFF | OFF | OFF | 99.9 | 0.1 | 3.000 |
| S1 | OFF | OFF | OFF | ON | 93.3 | 6.7 | 1.174 |
| S2 | OFF | OFF | ON | OFF | 86.6 | 13.4 | 0.873 |
| S3 | OFF | OFF | ON | ON | 80.0 | 20.0 | 0.699 |
| S4 | OFF | ON | OFF | OFF | 73.3 | 26.7 | 0.574 |
| S5 | OFF | ON | OFF | ON | 66.6 | 33.4 | 0.477 |
| S6 | OFF | ON | ON | OFF | 60.0 | 40.0 | 0.398 |
| S7 | OFF | ON | ON | ON | 53.3 | 46.7 | 0.331 |
| S8 | ON | OFF | OFF | OFF | 46.6 | 53.4 | 0.273 |
| S9 | ON | OFF | OFF | ON | 40.0 | 60.0 | 0.222 |
| S10 | ON | OFF | ON | OFF | 33.3 | 66.7 | 0.176 |
| S11 | ON | OFF | ON | ON | 26.6 | 73.4 | 0.134 |
| S12 | ON | ON | OFF | OFF | 20.0 | 80.0 | 0.097 |
| S13 | ON | ON | OFF | ON | 13.3 | 86.7 | 0.062 |
| S14 | ON | ON | ON | OFF | 6.6 | 93.4 | 0.030 |
| S15 | ON | ON | ON | ON | 0.0 | 100.0 | 0.000 |

To configure an average, use the following procedure:

1. From the AVERAGES sub-menu, select the average you want to configure.

2. The next screen prompts you to configure either the variable type or the time period of the selected average. Select VAR.

3. At the prompt, select one of the variables from the scrollable list and press Enter. To exit the screen without making a selection, press Esc.

4. Next, select PER to configure the time period of the selected average.

5. At the prompt, select one of the time periods from the scrollable list and press Enter. To exit the screen without making a selection, press Esc.

6. To configure another average, repeat steps 1 through 5. Once all desired averages are configured, press Send to send the average configurations to the intelligent electronics.

**Table 6-15. AVERAGES Sub-menu.**

| MENU ITEM | POSSIBLE VARIABLES | TYPICAL VALUE | DESCRIPTION | DEFAULT SETTING |
|---|---|---|---|---|
| **Average 1**<br>**Average 2**<br>**(read-only)** | N/A | N/A | Displays the current average value. Selecting each average displays the variable type and the time period of that average. | N/A |
| **Avg X Variable (read-only)** | None<br>Opacity<br>Transmittance<br>Optical Density<br>Extinction<br>Dust Concentration | Opacity (for Avg 1) | Displays the type of variable specified for the average calculation. | None |
| **Avg X Period (read-only)** | 15 sec<br>1 min.<br>2 min.<br>3 min.<br>4 min.<br>5 min.<br>6 min.<br>10 min.<br>12 min.<br>15 min.<br>20 min.<br>30 min.<br>60 min. | 6 min. | Displays the time period during which the variable measurements are collected. | 15 sec |

**d. ALARMS.** This sub-menu allows the configuration of two alarms. Through the relay outputs, each alarm can indicate when a variable is not within range. In the default system setup, alarms 1 and 2 control relay outputs 1 and 2, respectively. To access this sub-menu, select ALARMS from the DETAILED SETUP menu. The nine available menu items are explained in Table 6-16.

Alarm configuration is flexible. However, the alarms are normally configured for high values of opacity or opacity averages. Use the following procedure to configure the alarms:

1. From the ALARMS sub-menu, select ALARM CONFIG.

2. The next screen prompts you to select the Alarm 1 setting. Select one of the variables from the scrollable list and press Enter.

3. The next screen prompts you to select the alarm 1 type. Select one of the variables from the scrollable list and press Enter.

4. At the alarm 1 setpoint prompt, type the new value in the highlighted field and press Enter.

5. At the alarm 1 deadband prompt, type the new value in the highlighted field and press Enter.

6. Repeat steps 2 through 5 to configure alarm 2.

7. After configuring both alarms, the system returns to the ALARMS sub-menu. Verify that the settings reflect the latest changes.

**Table 6-16. ALARMS Sub-menu.**

| MENU ITEM | POSSIBLE VARIABLES | TYPICAL VALUE | DESCRIPTION | DEFAULT SETTING |
|---|---|---|---|---|
| **Alarm Configuration (method)** | N/A | N/A | Provides the procedure to change the alarm configurations. | N/A |
| **Alarm 1 Alarm 2 (read-only)** | None<br>Opacity<br>Transmittance<br>Optical Density<br>Extinction<br>Dust Concentration<br>Lx/Lt<br>Avg 1 through 12 | Opacity | Identifies the variable to monitor. | None |
| **Alarm 1 Type Alarm 2 Type (read-only)** | High<br>Low<br>None | High | Identifies which end of the variable range to monitor. For example, if a high alarm type is selected, the alarm will activate if the variable exceeds the alarm setpoint. If a low alarm type is selected, the alarm will activate if the variable falls below the alarm setpoint. Selecting none will not configure an alarm. | None |
| **AL1 Setpoint AL2 Setpoint (read-only)** | XXX.XX% | 100.00% | Identifies the high or low limit of the variable, depending on the alarm type setting. | 0 |
| **AL1 Deadband AL2 Deadband (read-only)** | X.XX% | 1.0% | Represents the value that must be subtracted from the setpoint before the alarm will deactivate. For a high alarm, the variable will activate the alarm if its value exceeds the alarm setpoint. The alarm will not deactivate until the variable value drops below the alarm setpoint minus the deadband. The deadband is designed to prevent a chattering alarm. | 0 |

**Table 6-17. DUST SETUP Sub-menu.**

| MENU ITEM | TYPICAL VALUE | DESCRIPTION | DEFAULT SETTING |
|---|---|---|---|
| **Dust C (read-only)** | 0.400 | Offset constant determined by gravimetric sampling. | 0 |
| **Dust K (read-only)** | 66.800 | Gain constant determined by gravimetric sampling. | 0 |
| **Date (read-only)** | 09/30/97 | Records when the dust constants were last changed (MM/DD/YY). The system automatically updates this parameter. | N/A |
| **Time (read-only)** | 14:32 | Records when the dust constants were last changed (HH:MM). The system automatically updates this parameter. | N/A |
| **Dust Configuration (method)** | N/A | Provides the procedure to change the dust constants. | N/A |

**e. DUST SETUP.** The menu items in this sub-menu enable the unit for dust concentration measurements. To access this sub-menu, select DUST SETUP from the DETAILED SETUP menu. The five available menu items are explained in Table 6-17.

After iso-kinetic sampling has occurred and data has been plotted for the c and k values, c and k can be entered as constants.

Use the following procedure to enter the values needed to relate extinction readings to the dust concentration (DC).

1. From the DUST SETUP sub-menu, select DUST CONFIGURATION.

2. The next screen prompts you to enter the dust C constant. Type the new value in the highlighted field and press Enter.

3. The next screen prompts you to enter the dust K constant. Type the new value in the highlighted field and press Enter.

4. A "Writing dust constants" message appears as the system updates. Then, the system returns to the DUST SETUP sub-menu. Verify that the constants and date and time reflect the latest changes.

**6-10. REVIEW MENU.** The REVIEW menu summarizes the revision information for both the IG-1 software and the stack software and displays the OPM 2000R system serial number. To access this menu, select the DEVICE SETUP from the online menu and select REVIEW. The three available sub-menus are explained in Table 6-18.

**Table 6-18. REVIEW Menu.**

| SUB-MENU | DESCRIPTION |
|---|---|
| **IG-1 S/W Version (read-only)** | Identifies the revision level and release date of the IG-1 software. The revision date includes the year, month, day, hour, and minute. |
| **Stack S/W Version (read-only)** | Identifies the revision level and release date of the stack software. The release date includes the year, month, day, hour, and minute. |
| **Serial Numbers (read-only)** | Displays the serial number of the OPM 2000R system. |

**6-11. HART COMMUNICATOR MENU TREE FOR OPM 2000R.** The HART menu tree shown in Figure 6-10 identifies all of the displays and procedures used to monitor and control the OPM 2000R system.

The first column in Figure 6-10 represents the online menu. From that menu, only the DEVICE SETUP selection subdivides into more specific menu options, which consist of methods and/or informational displays. A method is a procedure that you can use to perform a specific task. If a method is not associated with a menu option, the option will be a read-only or read, write (editable) display.

To select a menu or menu option, either press the right arrow action key or use the alphanumeric keypad and press the number shown on the display that corresponds to the menu option. For further information about a specific menu option, refer to paragraphs 6-6 through 6-10.

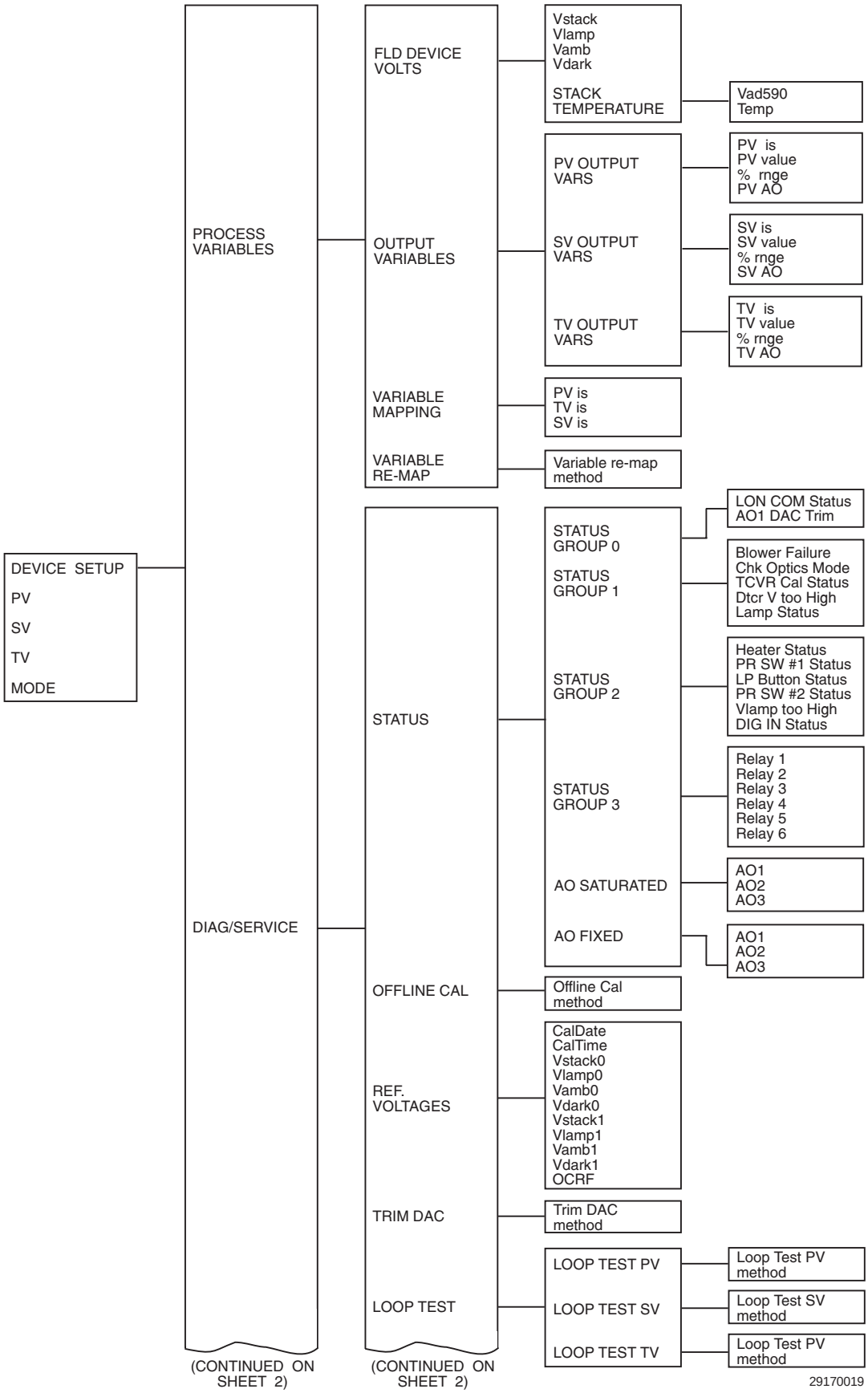



**Figure 6-10. HART Menu Tree for the OPM 2000R (Sheet 1 of 3)**

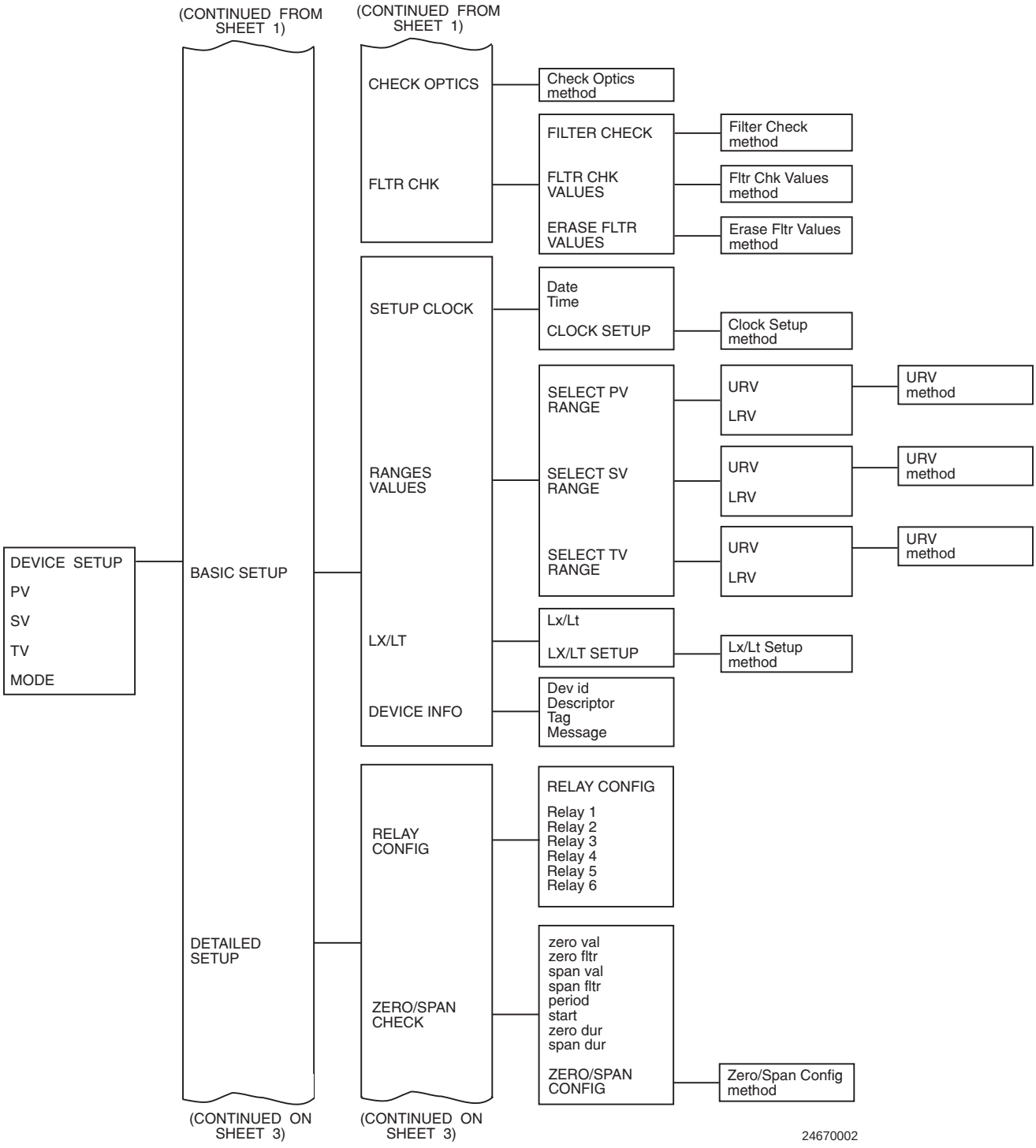



**Figure 6-10. HART Menu Tree for the OPM 2000R (Sheet 2 of 3)**

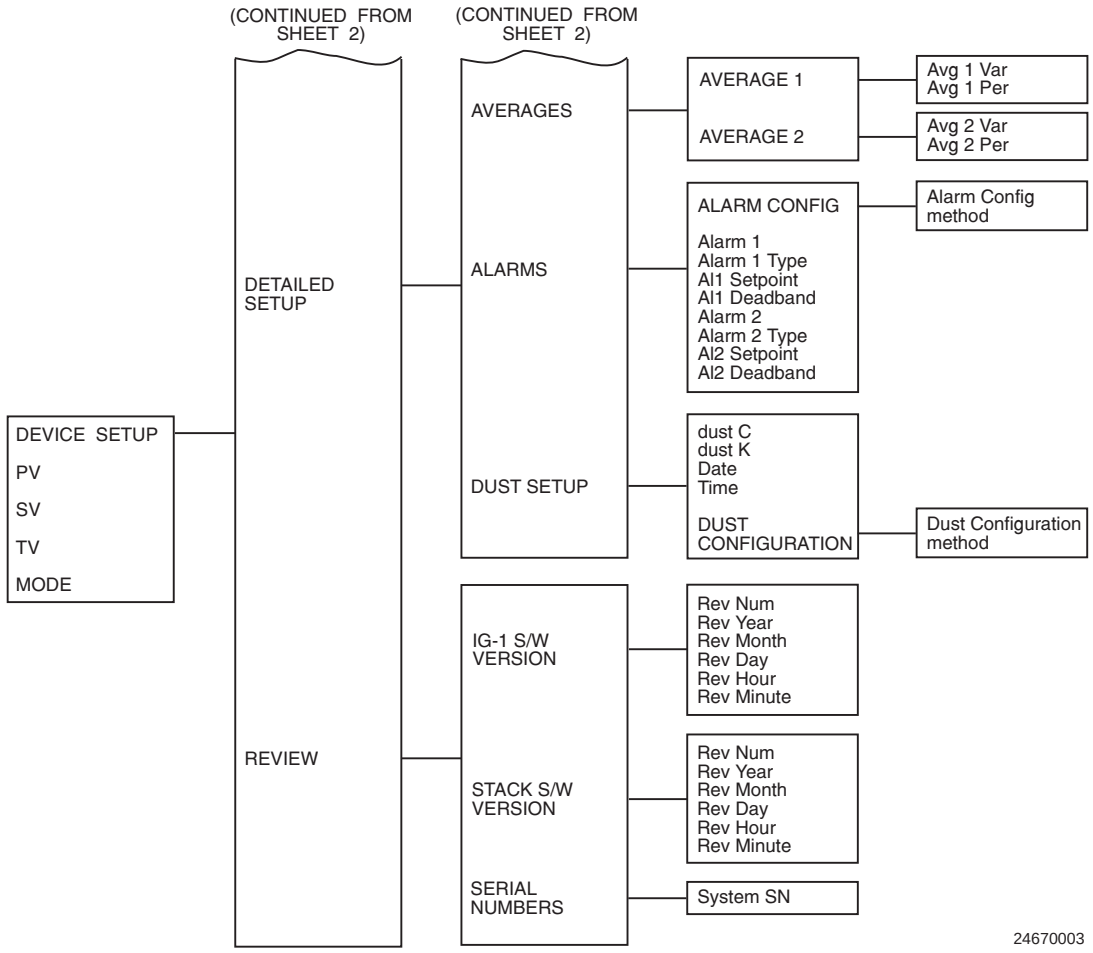



**Figure 6-10. HART Menu Tree for the OPM 2000R (Sheet 3 of 3)**

# SECTION VII. TROUBLESHOOTING

**WARNING**

**Install all protective equipment covers and safety ground leads after troubleshooting. Failure to replace covers and ground leads could result in serious injury or death.**

**7-1. GENERAL.** This section covers the system mode fault indicators generated from system self-diagnostics and provides a general troubleshooting chart and simple test procedures to correct possible fault conditions.

**7-2. SYSTEM MODE INDICATORS.** The OPM 2000R Opacity/ Dust Density Transmitter has built-in system diagnostics features that indicate fault conditions. These indications appear in the MODE line of the HART communicator online menu. Normal opacity measurement functions cannot proceed when a system status alarm is indicated. The following modes indicate a fault condition.

**a. CALF.** This fault occurs if the last calibration failed for any of the following voltage conditions:

| | |
|---|---|
| $V_{STACK\ 0} - V_{LAMP\ 0}$ | > 1.5 VDC |
| $V_{LAMP\ 0} - V_{STACK\ 0}$ | > 1.5 VDC |
| $V_{STACK\ 0} - V_{AMB\ 0}$ | < 2.0 VDC |
| $V_{STACK\ 0} - V_{STACK\ 1}$ | < 1.0 VDC |
| $V_{LAMP\ 0} - V_{DARK\ 0}$ | < 2.0 VDC |
| $V_{STACK\ 0}$ | > 4.75 VDC |
| $V_{LAMP\ 0}$ | > 4.75 VDC |
| $V_{DARK\ 1}$ | < -0.50 VDC |

**b. COMF.** This fault indicates a communication failure caused by bad connections, faulty stack LON board microprocessor, or corrupt stack LON board EEPROM.

**c. SYSFLT.** This fault occurs if there is a lamp failure ($V_{LAMP} - V_{DARK} < 1.0$ VDC), blower failure, the detector voltage is too high ($V_{LAMP}$ or $V_{STACK} > 4.75$ V), or the lamp voltage is too high.

**d. CALF&SYSFLT.** This fault indicates that both a CALF and SYSFLT have occurred independently of each other.

**7-3. DIAGNOSTICS.** The OPM 2000R has a self-diagnostic feature to aid in troubleshooting. Before troubleshooting, access the STATUS sub-menu of the DIAG/SERVICE menu to find up-to-date, ON/OFF indications of system status and fault conditions that will help direct your troubleshooting efforts. Refer to Table 7-1 for explanations of these indicators.

**Table 7-1. Diagnostic Indicators.**

| MENU ITEM | FAULT OR STATUS INDICATION | DESCRIPTION |
|---|---|---|
| **STATUS GROUP 0** | | |
| LON COM Status | STATUS | ON—LON communication problem exists, such as bad connections or signal path interference.<br>OFF—Normal condition. |
| AO1 DAC Trim | STATUS | ON—4-20 mA signal loop needs to be calibrated.<br>OFF—Calibration not needed. |
| **STATUS GROUP 1** | | |
| Blower Failure | FAULT | ON—Blower problem exists.<br>OFF—Normal condition. |
| Chk Optics Mode | STATUS | ON—System is in the check optics mode.<br>OFF—Normal condition. |
| TCVR Cal Status | STATUS | ON—Transceiver needs to be calibrated.<br>OFF—Calibration is not needed. |
| Dter V too High | FAULT | ON—Measured voltage readings are > 4.75 V.<br>OFF—Normal condition. |
| Lamp Status | STATUS | ON—Lamp problem exists.<br>OFF—Normal condition. |
| **STATUS GROUP 2** | | |
| Heater Status | STATUS | ON—Heater is ON.<br>OFF—Heater is OFF. |
| Purge Air Flow Switch #1 (PR SW #1) Fault | FAULT | ON—Problem exists with blower on transceiver.<br>OFF—Normal condition. |
| Lighted Pushbutton Pressed | FAULT | ON—Pushbutton either pressed or faulty.<br>OFF—Normal condition. |
| Purge Air Flow Switch #2 (PR SW #2) Fault | FAULT | ON—Problem exists with blower on retroreflector.<br>OFF—Normal condition. |
| $V_{LAMP}$ too High | FAULT | ON—Lamp voltage is too high.<br>OFF—Normal condition. |
| DIG IN Status | STATUS | ON—Digital input is closed (on).<br>OFF—Normal condition. |
| **STATUS GROUP 3** | | |
| Relays 1 through 6 | STATUS | Indicates the ON or OFF status of each relay. Check the RELAY CONFIG sub-menu in the DETAILED SETUP menu for the current configuration of each relay. |
| **AO SATURATED** | | |
| AO1 through AO3 | FAULT | ON—Specified analog output is > 20 mA<br>OFF—Normal condition. |
| **AO FIXED** | | |
| AO1 through AO3 | STATUS | ON—System is performing a TRIM DAC or LOOP test on the indicated analog output and the system is in the FIXED MA mode.<br>OFF—Normal condition. |

**Table 7-2. Troubleshooting Chart.**

| | ALARM, or other INDICATION | POSSIBLE CAUSE | CORRECTIVE ACTION |
|---|---|---|---|
| 1. | CALF | OPM 2000R failed last calibration | Recalibrate OPM 2000R. |
| 2. | COMF | Failed communications cable | Check wiring and connections between intelligent electronics and transceiver. |
| | COMF and stack LON board status LED on | Failed microprocessor | Replace stack LON board per paragraph 8-3.g. |
| | COMF and stack LON board status LED blinking | EEPROM missing or damaged | Install new EEPROM. |
| 3. | SYSFLT | | |
| | Blower failure | Plugged purge air filter | Check filters on bottom of weather housing and at blower intake. Clean per paragraph 8-2.d and 8-2.e, if necessary. |
| | | Faulty check valve | Repair or replace check valve. |
| | | Faulty sensor tubing from air lens to purge air failure flow switch | Ensure sensor tube connections are airtight. Check for kinks, cracks, and punctures in the line. Repair or replace sensor tubes as needed. |
| | | Failed purge air flow switch | Check that wires are properly connected. Check blowers and air system. Replace flow switch, if necessary. |
| | | Blower failure | Inspect blower motor and repair or replace, if necessary. Check circuit breaker to blower motor. Reset circuit breaker as necessary. |
| | Detector voltage too high ($V_{LAMP}$ or $V_{STACK}$ > 4.75 V) | Faulty detector board | Adjust detector amplifier potentiometer per paragraph 8-3.d. Perform detector test procedure per paragraph 7-4.a. Repair or replace as indicated. |
| | | Faulty power supply | Perform power supply test procedure per paragraph 7-4.b. Repair or replace faulty power supply. |
| | Lamp failure ($V_{LAMP}$ - $V_{DARK}$ < 1.0 VDC) | Defective lamp | Replace lamp per paragraph 8-3.b. |
| | | Blown LCW/lamp fuse | Replace fuse per paragraph 8-5.b. |
| | | Lamp voltage too high or too low (should be about 4.6 VDC) | Check voltage to lamp. Replace power supply if necessary. |
| | | LCWs #1 and #2 not activating properly | Perform LCW test procedure per paragraph 7-4.c. Replace LCW(s) per paragraph 8-3.f, if necessary. |
| | | Faulty electrical connection between detector/amplifier board and analog-to-digital converter | Check electrical cable and connection. Repair or replace as necessary. |
| | | Faulty analog-to-digital converter on stack LON board | Replace stack LON board per paragraph 8-3.g. |

**Table 7-2. Troubleshooting Chart (Continued).**

| ALARM, or other INDICATION | POSSIBLE CAUSE | CORRECTIVE ACTION |
|---|---|---|
| 3. SYSFLT (Continued) | | |
| Lamp voltage too high | Lamp voltage too high (should be about 4.6 VDC) | Check voltage to lamp. Replace power supply if necessary. |
| CAL/CHECK pushbutton pressed | Pushbutton pressed or faulty (becomes shorted) | Replace if defective. |
| 4. CALF&SYSFLT | Calibration failure and a system fault occurred | Refer to the possible causes and corrective actions in this table for both CALF and SYSFLT to correct the fault condition. |
| 5. All voltages from detector low or the same | Blown detector/amplifier fuse | Replace fuse per paragraph 8-5.b. |
| | Blown LCW/lamp fuse | Replace fuse per paragraph 8-5.b. |
| | Faulty detector board | Readjust detector amplifier potentiometer per paragraph 8-3.d. Perform detector test procedure per paragraph 7-4.a. Repair or replace as required. |
| | Faulty power supply | Perform power supply test procedure per paragraph 7-4.b. Repair or replace as required. |
| 6. Voltage readings too high or too low | Gain out of adjustment | Adjust detector amplifier potential per paragraph 8-3.d. |
| 7. Heater malfunction | Blown heater fuse | Replace fuse per paragraph 8-5.c. |
| | Burned out or shorted heater | Replace heater. |
| | Faulty temperature sensor | Replace entire stack LON board per paragraph 8-3.g. |
| | Faulty heater control module | Replace heater control module (U12). |
| 8. Opacity or Dust Reading High | Dirty optics | Clean the lens, windows, and corner cube per paragraph 8-2.b. Verify air lens functions properly. Repair if necessary. |
| | Condensation on optics | Clean the lens, windows, and corner cube. Check the heater and heater circuit. Using an AC voltmeter, verify the line voltage across the TO HEATER terminals on the stack LON board. Replace the heater if necessary. |
| | Closed or partially closed air lens seal plate | Slide seal plate to fully open position. Ensure seal plate remains open unless manually closed. |
| | OPM out of alignment | Check mounting rigidity. Reinstall and tighten mounting hardware as required. Perform optical alignment of transceiver and retroreflector per Section V. |
| | OPM out of calibration | Recalibrate OPM “offline” or under clear stack conditions per paragraph 6-7.b. |
| | LCW failure | Perform LCW test procedure per paragraph 7-4.c. Replace LCW(s) per paragraph 8-3.f as necessary. |

**Table 7-2. Troubleshooting Chart (Continued).**

| ALARM, or other INDICATION | POSSIBLE CAUSE | CORRECTIVE ACTION |
|---|---|---|
| 9. Opacity Low or Negative | "Online" mis-calibration with particulate present | Recalibrate "offline" or under clear stack conditions per paragraph 6-7.b. |
| | OPM 2000R out of alignment | Check OPM alignment. If necessary, realign the OPM 2000R per Section V. |
| | Insufficient time for system to stabilize after CHECK OPTICS procedure | Wait at least 30 minutes after CHECK OPTICS procedure before performing the offline calibration. |
| | Faulty LCW 2 (multi-sectored LCW) | Perform LCW test procedure per paragraph 7-4.c. Replace LCW 2 per paragraph 8-3.f, if necessary. |
| | **NOTE**<br>**Opacity 105% indicates a fault other than blower failure.** | |
| 10. Opacity 105% | High voltages (>4.75 VDC) from detector/amplifier board saturating the analog-to-digital converter, causing high voltage readings | Check FLD DEVICE VOLTS sub-menu under PROCESS VARIABLES menu to access last detector voltage readings. Perform detector test procedure per paragraph 7-4.a. Make repairs as needed. |
| | Communication error due to bad signal cable, bad connections, or signal interference | Check signal cable for damage and bad connections. Repair as necessary. Ensure the signal path is clear of high voltage lines, transformers, electric motors, and radio frequency transmitters. Reroute the signal path if required. |
| | System out of calibration | Calibrate OPM 2000R per paragraph 6-7.b. |
| 11. Pushbutton pressed | CAL/CHECK pushbutton pressed or faulty | Replace switch if defective. |
| 12. Stack LON board status LED blinking or on steady | Missing stack LON board software chip or bad stack LON board | Install stack LON board software chip (1A99073G01) or replace stack LON board. |

## 7-4. TEST PROCEDURES.

**WARNING**

**Death or serious injury is possible when working near exposed electrical terminals and power supplies. Use proper safety precautions when working near live lines and terminals.**

**a. Detector Test Procedure.** The detector/amplifier board outputs one voltage reading every second during the RUN mode. Abnormal voltages may help determine a problem in the light path. A digital voltmeter can be used to measure the voltages in succession. Typical values are as follows:

$V_{DARK}$ = +0.2 VDC
$V_{LAMP}$ = +3.6 VDC
$V_{AMB}$ = +0.7 VDC
$V_{STACK}$ = +2.8 VDC

Check the voltage readings at the signal exit from the left side of R4 on the detector/amplifier board (Figure 8-4). If necessary, adjust amplifier gain by adjusting potentiometer R1. If the output signal voltages are not acceptable, perform the power supply test procedure for power supply 2 (PS2) per paragraph 7-4.b.2.

**b. PS1 and PS2 Power Supply Test Procedures.** The stack LON board (Figure 2-11) contains two power supplies, PS1 and PS2. PS1 supplies +5 VDC and ±15 VDC. PS2 supplies the LCW driver chip (U6) with 60 VDC. Refer to Figures 2-11 and 7-1 and test PS1 and PS2 with a digital voltmeter as follows:

1. Power Supply 1 (PS1). Test PS1 using the test points as follows:

   TP15 +5 VDC referenced to TP1
   TP16 -5 VDC referenced to TP1
   TP13 +5 VDC referenced to TP2
   TP2 Digital Ground
   TP9 +15 VDC referenced to TP1
   TP1 Analog Ground
   TP11 -15 VDC referenced to TP1

2. Power Supply 2 (PS2). Test PS2 using the test points as follows:

   TP12 +60 VDC referenced to TP2

STACK LON BOARD (PARTIAL)

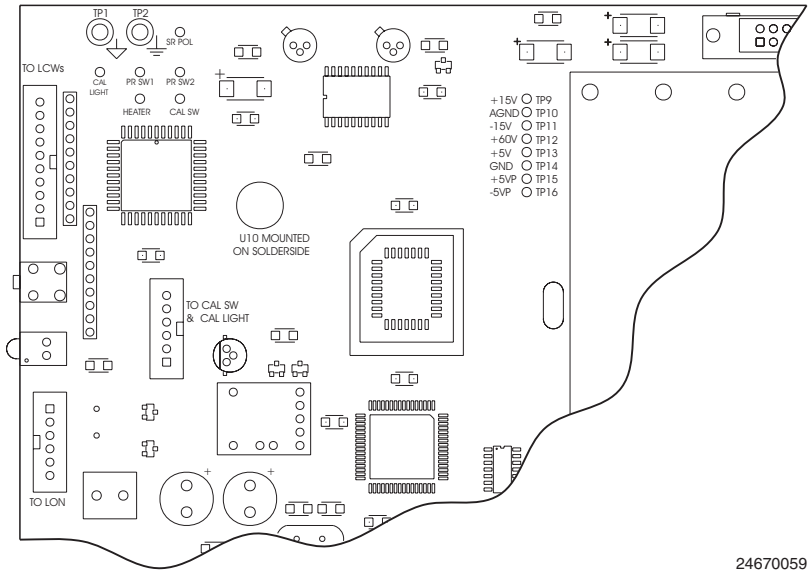



**Figure 7-1. PS1 and PS2 Test Points**

**c.** **<u>LCW Test Procedure</u>.** Alternating current causes LCWs to change from translucent to transparent. The difference can usually be seen by observing the LCWs in the optic channel. Test LCW 1 and LCW 2 as follows:

**WARNING**

**Death or serious injury is possible when working near exposed electrical terminals and power supplies. Use proper safety precautions when working near live lines and terminals.**

**CAUTION**

**LCWs will be damaged by direct current. Do not test LCWs for resistance with a digital voltmeter. Avoid shorting the leads at the LCW cable connectors.**

1. Check light path voltages per paragraph 7-4.a. If the voltages are significantly different, replace the least transparent LCW.

2. Being careful to avoid shorting the leads, check the voltage entering the LCWs.

3. If the 60 V square wave at 100 Hz is present, the LCW should change from translucent to transparent. Replace the LCW if defective per paragraph 8-3.f.

4. If 60 V is not present at the LCW, perform the PS2 test procedure per paragraph 7-4.b.2.

5. If the problem persists, replace the stack LON board.

# SECTION VIII. SERVICE AND NORMAL MAINTENANCE

**WARNING**

**Install all protective equipment covers and safety ground leads after equipment repair or service. Failure to install covers and ground leads could result in serious injury or death.**

**8-1.** **GENERAL.** This section describes the routine maintenance of the Rosemount OPM 2000R Opacity/Dust Density Transmitter. The amount of maintenance required depends on the environment to which the instrument is subjected. A transmitter that is subjected to extremely dusty conditions, vibration, and movement will require considerably more maintenance than a unit that is rigidly mounted in a clean, dust-free atmosphere.

A preventive maintenance schedule is included in Appendix B. Ensure all routine maintenance procedures are performed at the specified intervals.

**8-2.** **PREVENTIVE MAINTENANCE.**

**a.** If the opacity/dust density transmitter reading is too high, check the alignment of the optics. If the unit is properly aligned, then clean the transceiver window and the retroreflector corner cube. If the reading is still too high, recalibrate the unit.

**b.** Inspect and clean the transceiver window and the retroreflector corner cube as follows:

1. Remove weather housings (9, Figure 2-1) on the transceiver and retroreflector modules.
2. Remove electronics housing (14, Figure 2-2) from the optical bench assembly by releasing the four toggle clamps that hold the housing to mounting plate (27).
3. Release the toggle latches on the front left side of the transceiver and remove window access plate (41) and gasket (40).
4. Clean window (37) with a good lens cleaning solution and a lens wipe. DO NOT use a towel or rag that may scratch the window or leave lint behind.
5. Install window access plate (41) and gasket (40).
6. Install electronics housing (14).
7. Unscrew endcap on the retroreflector module (Figure 5-1). The corner cube is mounted inside the endcap.
8. Clean the corner cube with a good lens cleaning solution and a lens wipe. DO NOT use a towel or rag that may scratch cube or leave lint behind.
9. Install the endcap on the retroreflector.
10. Install weather housings (9, Figure 2-1) on the transceiver and retroreflector modules.

**c.** Check the alignment of the modules using the optical alignment sight. If necessary, realign modules as described in Section V.

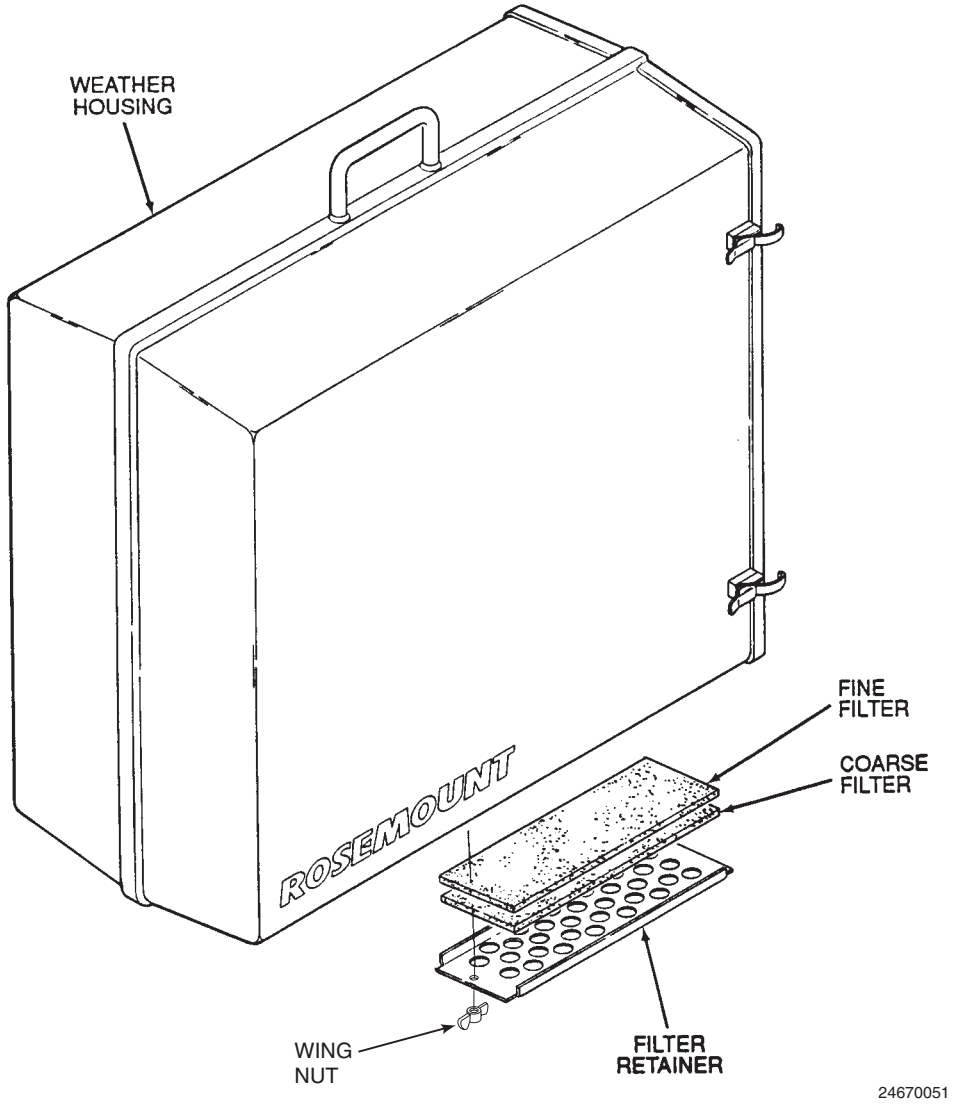



**Figure 8-1. External Filters - Exploded View**

**d.** If the unit is installed in a dirty environment, clean the external filters that are located on the weather housings every two months (every three months if in a clean environment) as follows:

1. Remove the filter retainer by unscrewing the wing nuts (Figure 8-1).

2. Remove the coarse and fine filters from the bottom of the weather housing.

3. Immerse the filters in a mild detergent solution such as common dishwashing detergent. Gently wring out each filter.

4. Install the filters. Make sure the fine filter is installed before the coarse filter.

5. Install the filter retainer and secure with the wing nuts.

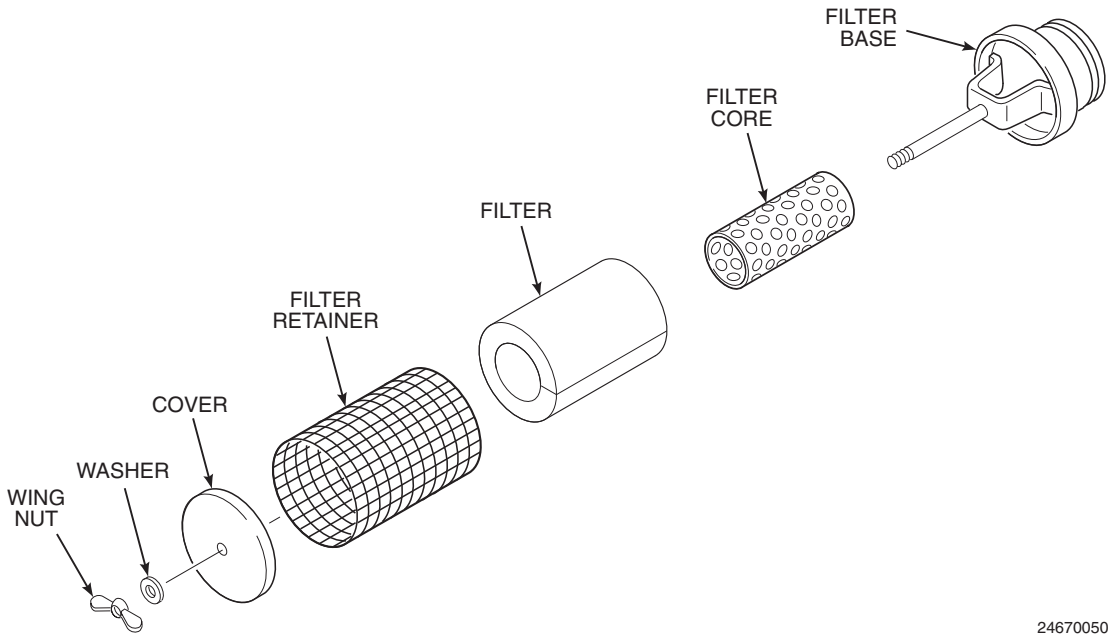



**Figure 8-2. Internal Filter - Exploded View**

**e.** Check the internal filters on the transceiver and retroreflector modules after every other external filter cleaning. If a filter is visibly dirty, clean as follows:

1. Remove the entire filter assembly by unscrewing the filter base (Figure 8-2) from the blower motor.

2. Unscrew the wing nut from the filter base and remove the washer.

3. Remove cover and filter retainer and slide the filter element from the filter core.

4. Immerse the filter in a mild detergent solution such as common dishwashing detergent. Gently wring out the filter.

5. Slide the filter element onto the filter core.

6. Install the retainer, cover, and washer and secure the filter assembly with the wing nut.

7. Install the filter assembly onto the blower motor.

**8-3. REPAIR.**

**a. Optical Assembly (1, Figure 2-1).**

1. Removal.

**CAUTION**

**The optical enclosure cover should only be removed in a clean, dust-free environment. Unless the transceiver is mounted in a clean area, remove the optical assembly from the stack and perform repairs in a suitable place. Use the following procedure to remove the optical assembly.**

**A sliding seal plate on the air lens assembly prevents exhaust gases from backing up into the optical assembly. Be sure to close the seal plates whenever the purge air supply is interrupted. Failure to close the plates can lead to equipment damage.**

(a) Remove weather housing (9).

(b) Close air window seal plate (60).

(c) Turn off power to the transceiver and blower.

(d) Unplug power cable (2) and communications cable (3) from optical assembly (1).

(e) Remove four nuts (65) and lockwashers (66) that secure optical assembly (1) to air lens assembly (58) and remove the optical assembly.

(f) Replace weather housing (9) on the transceiver.

(g) Set optical assembly (1) in a clean area.

2. Installation.

(a) Remove weather housing (9) from the transceiver.

(b) Secure optical assembly (1) to air lens assembly (58) with four lockwashers (66) and nuts (65).

(c) Plug communications cable (3) and power cable (2) into optical assembly (1).

(d) Turn on power to the transceiver and blower.

(e) Open air window seal plates (60).

(f) Install weather housing (9).

**b. Lamp Replacement.**

1. Remove the optical assembly from the transceiver module per paragraph 8-3.a.1.

2. Remove electronics housing (14, Figure 2-2) from the optical bench assembly by releasing the four toggle clamps that hold the housing to mounting plate (27).

3. Remove thumbscrew (2) and cover plate (1).

4. Remove push-on connectors (1, Figure 8-3) from the terminals of lamp (2).

5. Remove lock nut (3).

6. Unscrew and remove lamp (2) from lamp holder (4).

7. Thread the new lamp into place until the front of the bulb is about 1/2 in. (12.70 mm) from the lamp holder.

8. Thread lock nut (3) onto lamp (2) and tighten the lock nut against lamp holder (4). Ensure the bulb filament remains parallel to the bottom plate of the optic channel.

9. Reconnect push-on connectors (1) to the lamp terminals.

10. Reinstall cover plate (1, Figure 2-2) and secure with thumbscrew (2).

| ITEM | DESCRIPTION |
|---|---|
| 1 | Push-on Connectors |
| 2 | Lamp |
| 3 | Lock Nut |
| 4 | Lamp Holder |

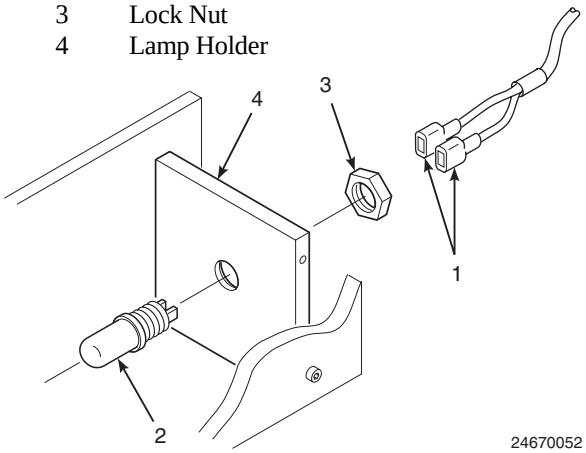



**Figure 8-3. Lamp Replacement**

11. Recalibrate the opacity transmitter. Refer to the offline calibration procedure per paragraph 6-7.b.

12. Recalibrate the zero jig per paragraph 8-4.a.

13. Install electronics housing (14).

14. Install optical assembly (1, Figure 2-1) in the transceiver module per paragraph 8-3.a.2.

**c. <u>Detector/Amplifier Board Replacement</u>.**

1. Remove optical assembly (1, Figure 2-1) from the transceiver module per paragraph 8-3.a.1.

2. Remove electronics housing (14, Figure 2-2) from the optical bench assembly by releasing the four toggle clamps that hold the housing to mounting plate (27).

3. Disconnect the plug-in connector at J1 (Figure 8-4).

4. Remove screws (16, Figure 8-5) and star washers (15) securing detector/amplifier board (14) to the optical mounting channel.

5. Remove the detector/amplifier board (14) from the optical mounting channel.

6. Check the jumper at JM1 or JM2 on the old board (Figure 8-4). Ensure the replacement board's jumper is at the same position (JM1 or JM2).

7. Install the new board to the mounting channel and secure with four screws (16, Figure 8-5) and star washers (15).

8. Reconnect the plug-on connector to J1 (Figure 8-4).

9. Refer to paragraph 8-3.d and check the gain of the new detector/amplifier board.

**d. <u>Gain Adjustment</u>.**

1. Apply power and ensure the LON communications is connected to the optical assembly.

   (a) If the optical assembly has been removed from the transceiver module, connect the power and LON test cables supplied with the OPM 2000R to power cable (30, Figure 2-2) and communications cable (29). Connect the power test cable to the correct AC voltage source, and connect the test LON cable to the LON (ECHELON) connector on the intelligent electronics.

   (b) If the optical assembly is still mounted to the transceiver module, remove weather housing (9, Figure 2-1) and electronics housing (14, Figure 2-2).

2. Using the HART Communicator, view the $V_{STACK}$ or $V_{LAMP}$ voltages from the FLD DEVICE VOLTS sub-menu of the PROCESS VARIABLES menu.

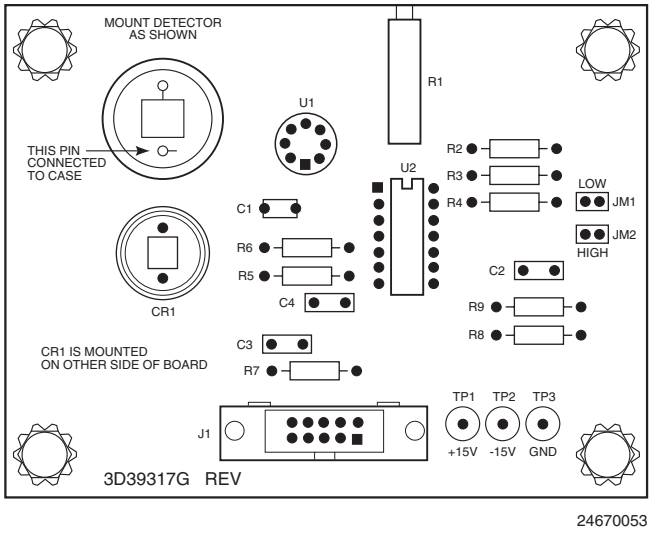
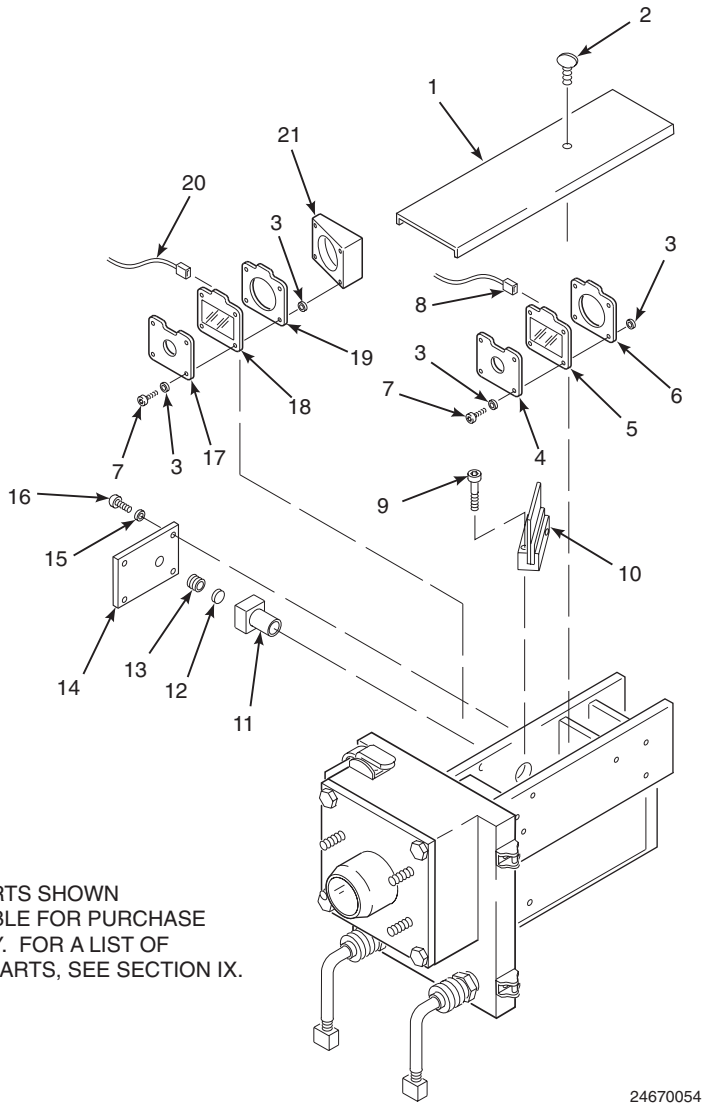



**Figure 8-4. Detector/Amplifier Board**

| ITEM | DESCRIPTION |
|---|---|
| 1 | Cover Plate |
| 2 | Thumbscrew |
| 3 | O-Ring |
| 4 | Aperture |
| 5 | LCW 1 |
| 6 | Aperture |
| 7 | Socket Head Screw |
| 8 | LCW 1 Plug-in Connector |
| 9 | Socket Head Screw |
| 10 | Beam Splitter |
| 11 | Detector Mount |
| 12 | Green Filter |
| 13 | Detector |
| 14 | Detector/Amplifier Board |
| 15 | Internal Star Washer |
| 16 | Socket Head Screw |
| 17 | Reflector |
| 18 | LCW 2 |
| 19 | Aperture |
| 20 | LCW 2 Plug-in Connector |
| 21 | Objective Lens and Iris |




NOTE: NOT ALL PARTS SHOWN ARE AVAILABLE FOR PURCHASE SEPARATELY. FOR A LIST OF AVAILABLE PARTS, SEE SECTION IX.

**Figure 8-5. Beam Splitter Adjustment and LCW Replacement**

3. If $V_{STACK}$ and $V_{LAMP}$ are equal to each other ±0.5 V, go to step 4. If not, remove thumbscrew (2, Figure 2-2) and cover plate (1). Loosen the screw on the LCW 2 mounting block (Figure 8-6). With the cover plate, cover up the part of the optical mounting channel not needed to block excess light from reaching the detector. Move the slider (Figure 8-6), which opens and closes the iris, to adjust $V_{LAMP}$ until it is within ±0.5 V of $V_{STACK}$. Ensure light still reflects off of the internal reflector behind LCW 2. Tighten the screw and install the cover plate and thumbscrew.

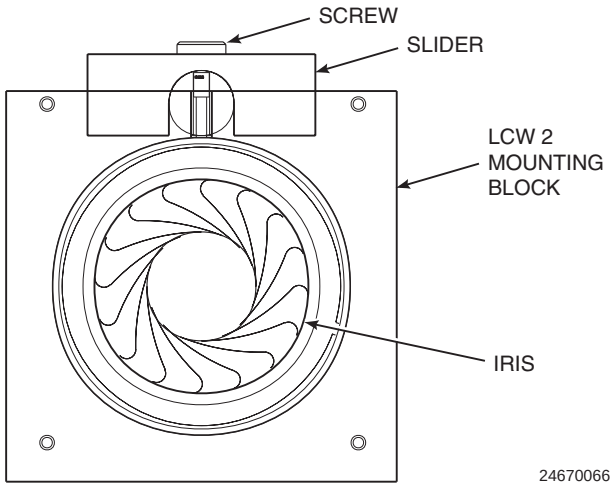



**Figure 8-6. $V_{LAMP}$ Adjustment**

4. If $V_{STACK}$ and $V_{LAMP}$ are within the +3.0 to +4.0 VDC range, no adjustment is needed. However, for best performance, bring $V_{STACK}$ or $V_{LAMP}$, whichever is greater, to +4.0 ±0.1 V. If $V_{STACK}$ and $V_{LAMP}$ are out of the +3.0 to +4.0 VDC range, adjust potentiometer R1 on the detector/amplifier board (Figure 8-4) until $V_{STACK}$ or $V_{LAMP}$, whichever is greater, is equal to +4.0 ±0.1 V.

   (a) If potentiometer R1 is turned all the way up and the voltage is still too low, remove the jumper from JM1, place it on JM2, and readjust R1.

   (b) If potentiometer R1 is turned all the way down and the voltage is still too high, remove the jumper from JM2, place it on JM1, and readjust R1.

5. Recalibrate the opacity transmitter per paragraph 6-7.b.

6. Install electronics housing (14, Figure 2-2).

7. Install optical assembly (1, Figure 2-1) in the transceiver module per paragraph 8-3.a.2.

**e. <u>Beam Splitter Alignment</u>.**

**NOTE**

**The beam splitter is aligned at the factory and should not require adjustment. However, it is possible that replacing the detector/amplifier board or loosening the beam splitter mounting hardware could result in misalignment, causing higher opacity readings.**

1. Set the transceiver and retroreflector modules on stands in a clean environment as described in paragraph 6-7.b.

2. Remove thumbscrew (2, Figure 8-5) and cover plate (1).

3. Remove detector/amplifier board (14) as described in paragraph 8-3.c.

4. Place a piece of translucent material, such as thin paper, over the detector hole in the optical unit.

5. Loosen screws (9).

6. Place the transceiver in the check optics mode per paragraph 5-1.c.

7. Select the $V_{STACK}$ setting.

**NOTE**

**The spot of light reflected by the beam splitter should be visible on the translucent material.**

8. Adjust beam splitter (10) until the spot of light is centered in the detector hole.

9. Exit the check optics mode.

10. Carefully tighten screws (9), ensuring the beam remains centered.

11. Install detector/amplifier board (14).

12. Calibrate the opacity transmitter according to paragraph 6-7.b.

13. Recalibrate the zero jig per paragraph 8-4.a.

**f. <u>Liquid Crystal Window Replacement</u>.** Refer to Figure 8-5.

1. Remove thumbscrew (2) and cover plate (1).

2. Remove plug-in connector (8 or 20) from the defective LCW.

3. Remove screws (7) and o-rings (3) securing the defective LCW.

**NOTE**

**When removing LCW 1 and apertures or removing LCW 2, aperture, and reflector, remember the order in which they were installed. These components must be replaced in the same order.**

4. If LCW 1 (5) is defective, remove LCW 1 and apertures (4 and 6). If LCW 2 (18) is defective, remove LCW 2, reflector (17), and aperture (19).

5. Install the new LCW 1 and apertures or LCW 2, aperture, and reflector and secure with o-rings (3) and screws (7). Ensure the components are installed in the same order they were removed.

6. Reconnect plug-in connector (8 or 20) to the new LCW.

7. Install cover plate (1) and secure with thumbscrew (2).

**g. Stack LON Board Replacement.**

1. Remove optical assembly (1, Figure 2-1) from the transceiver module per paragraph 8-3.a.1.

2. Remove electronics housing (14, Figure 2-2) by releasing the four toggle clamps that hold it to mounting plate (27).

3. Tag and remove all cables connected to stack LON board (50).

4. Remove screws (51) and internal star washers (52) securing stack LON board (50) to optical mounting channel (22).

5. Remove and replace stack LON board (50).

6. Install internal star washers (52) and screws (51) to secure stack LON board (50) to optical mounting channel (22).

7. Install all cables connected to stack LON board (50).

8. Install electronics housing (14).

9. Install optical assembly (1, Figure 2-1) in the transceiver module per paragraph 8-3.a.2.

## 8-4. ZERO JIG.

**a. Recalibration Procedure.** The zero jig must be adjusted to provide the same zero response as the opacity transmitter's simulated zero. A zero jig is specific only to the individual transmitter to which it has been calibrated. Make sure the serial numbers of the zero jig and transmitter match.

**NOTE**

**The primary zero alignment of the opacity transmitter must be performed under conditions in which the optical path is clear.**

1. Set up the opacity transmitter for a "clear path" condition by either of the following methods.

   (a) Ensure the monitored emission process is not in operation and that the monitored pathlength is free of particulate.

   (b) Remove the opacity transmitter from the installation and set the transmitter up under clear path conditions. Refer to paragraph 6-7.b.1 steps (a) through (f).

2. Ensure the opacity transmitter is set up to monitor the correct pathlength.

3. Ensure the opacity transmitter is optically aligned. Refer to Section V.

4. Record the opacity transmitter's response (in percent opacity) to the clear path condition.

5. Insert the zero jig on the transceiver.

   (a) Remove the window access plate and gasket from the transceiver.

   (b) Remove the keepers from the zero jig magnets and place the zero jig through the window access area. Slide the jig on the window flange and onto the locating pin.

   (c) Slightly rotate the jig back and forth until the 2 in. (50.8 mm) diameter raised section falls into place. The locator pin and the two permanent magnets hold the jig in position.

**NOTE**

**If the opacity transmitter needs to be calibrated, refer to paragraph 6-7.b before proceeding with step 6.**

6. Record the response to the transmitter's simulated zero condition as percent opacity corrected to stack exit conditions.

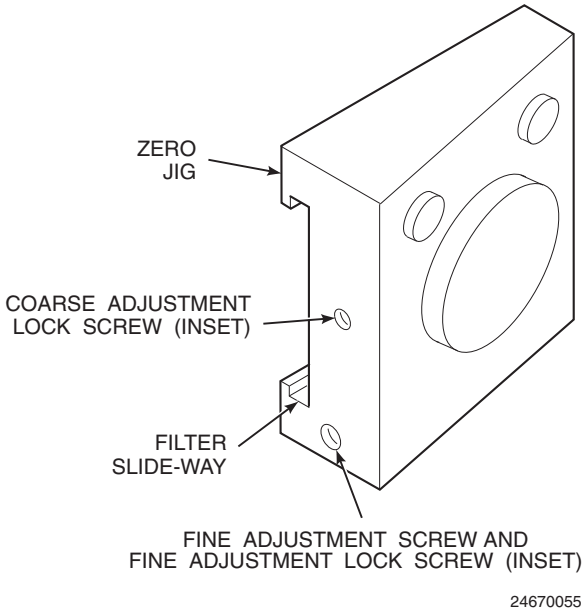



**Figure 8-7. Zero Jig Adjustment and Locking Screws**

**CAUTION**

**Be careful when tightening the coarse adjustment lock screw. Overtightening the screw will deform the iris.**

7. If necessary, adjust the zero jig to obtain the same response as the clear path condition (0% opacity). Loosen the coarse adjustment lock screw (Figure 8-7) to adjust the zero jig. After making the coarse adjustment, tighten the coarse adjustment lock screw to lock it in place.

8. To make a finer zero jig adjustment, remove the fine adjustment lock screw. Use the inside fine adjustment screw to obtain the same response as the clear path condition (0% opacity).

9. After making the adjustment, lock the calibrated setting in place by inserting the fine adjustment lock screw.

**CAUTION**

**The zero jig is a sensitive, calibrated instrument. Store the jig in its protective case when not in use. Failure to properly store the jig can lead to damage or an out-of-calibration condition.**

10. Place the keepers on the zero jig magnets and return the zero jig to its protective case.

11. If the opacity transmitter was removed in step 1, reinstall the transmitter.

12. Return the system to operation.

**b. Calibrated Zero Jig Application.** A calibrated zero jig with its locked setting is specific only to the opacity transmitter to which the jig was calibrated. The calibrated zero jig can be used to re-zero and re-span the specific transmitter without removing the transmitter from the stack and with the emission process running.

## 8-5. FUSE REPLACEMENT.

### a. Transceiver Module - 60 V Power Supply 2 (PS2) Fuse F1.

1. Remove optical assembly (1, Figure 2-1) per paragraph 8-3.a.1.

2. Remove electronics housing (14, Figure 2-2) by releasing the four toggle clamps that hold it to mounting plate (27).

3. Remove and replace fuse F1. Select the replacement fuse based on the following specifications and line voltages:

   (a) 0.1 A, 250 VAC, Slo Blo, CSA-approved fuse for 100 and 115 VAC line voltage

   (b) 0.063 A, 250 VAC, Slo Blo, CSA-approved fuse for 220 and 240 VAC line voltage

4. Install electronics housing (14) to mounting plate (27).

5. Install optical assembly (1, Figure 2-1) per paragraph 8-3.a.2.

**b. Transceiver Module - 5 V, ±15 V Power Supply 1 (PS1) Fuse F2.**

1. Remove optical assembly (1, Figure 2-1) per paragraph 8-3.a.1.
2. Remove electronics housing (14, Figure 2-2) by releasing the four toggle clamps that hold it to mounting plate (27).
3. Remove and replace fuse F2. Select the replacement fuse based on the following specifications and line voltages:
   (a) 0.25 A, 250 VAC, Slo Blo, CSA-approved fuse for 100 and 115 VAC line voltage
   (b) 0.125 A, 250 VAC, Slo Blo, CSA-approved fuse for 220 and 240 VAC line voltage
4. Install electronics housing (14) to mounting plate (27).
5. Install optical assembly (1, Figure 2-1) per paragraph 8-3.a.2.

**c. Transceiver Module - Heater Fuse F3.**

1. Remove optical assembly (1, Figure 2-1) per paragraph 8-3.a.1.
2. Remove electronics housing (14, Figure 2-2) by releasing the four toggle clamps that hold it to mounting plate (27).
3. Remove and replace fuse F3. Select the replacement fuse based on the following specifications and line voltages:
   (a) 5.0 A, 250 VAC, Slo Blo, CSA-approved fuse for 100 and 115 VAC line voltage
   (b) 2.5 A, 250 VAC, Slo Blo, CSA-approved fuse for 220 and 240 VAC line voltage
4. Install electronics housing (14) to mounting plate (27).
5. Install optical assembly (1, Figure 2-1) per paragraph 8-3.a.2.

**d. Transceiver Module - Stack Termination Board Fuses F1 and F2.**

1. Disconnect power to the transceiver module.
2. Remove weather housing (9, Figure 2-1) by releasing four toggle clamps (14) securing it to mounting plate (34).
3. Remove three screws (24) to remove top cover plate (25) to reveal stack termination board (41).
4. Remove and replace fuses F1 and F2 (5 A, 250 VAC, Slo Blo, CSA-approved fuses).
5. Install top cover plate (25) and secure with three screws (24).
6. Install weather housing (9).

**e. Type 4X Intelligent Electronics.**

1. Disconnect power to the intelligent electronics.
2. Open enclosure (1, Figure 3-5) cover.
3. Remove screws (14) and top cover plate (15).
4. Remove and replace fuse F1 (5 A, 250 VAC, Slo Blo, CSA-approved fuse).
5. Install top cover plate (15, Figure 3-5) and secure with screws (14).
6. Close enclosure (1) cover.

# SECTION IX. REPLACEMENT PARTS

## ENCODE MATRIX

**OPM 2000R –**

| | | |
|---|---|---|
| **INTELLIGENT ELECTRONICS** | NONE | 0 |
| | BASIC UNIT | 1 |
| | BASIC UNIT W/751 INDICATOR | 2 |
| | BASIC UNIT W/275 HART COMMUNICATOR | 3 |
| | BASIC UNIT W/751 & 275 | 4 |
| **INTELLIGENT ELECTRONICS OPTIONS** | NONE | 0 |
| | 115VAC/24VDC POWER SUPPLY | 1 |
| | 220VAC/24VDC POWER SUPPLY | 2 |
| | 115VAC/TYPE 4X ENCLOSURE W/POWER SUPPLY | 3 |
| | 220VAC/TYPE 4X ENCLOSURE W/POWER SUPPLY | 4 |
| | 115VAC/TYPE 4X ENCLOSURE W/P.S. AND HEATER | 5 |
| | 220VAC/TYPE 4X ENCLOSURE W/P.S. AND HEATER | 6 |
| **TRANSCEIVER VOLTAGE** | NONE | 1 0 |
| | 100V | 1 1 |
| | 115V | 1 2 |
| | 220V | 1 3 |
| | 240V | 1 4 |
| **PATHLENGTH LF** | NONE | 1 0 |
| | 3 - 5 FEET | 1 1 |
| | 5 - 10 FEET | 1 2 |
| | 10 - 20 FEET | 1 3 |
| | 20 - 26 FEET | 1 4 |
| **ZERO JIG** | NONE | 0 0 |
| | 3 - 20 FEET | 0 1 |
| | 20 - 26 FEET | 0 2 |
| **CERTIFICATION** | NONE | 0 0 |
| | CERT. OF COMPLIANCE | 0 1 |
| | CSA | 0 2 |
| | CSA & CERT. OF COMPLIANCE | 0 3 |
| **ALIGNMENT TUBE** | NONE | 0 0 |
| | INCLUDED | 0 1 |

## DECODE MATRIX

**OPM 2000R –**

**INTELLIGENT ELECTRONICS & OPTIONS**

| | | 00 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BASIC UNIT (IN BLACK BOX) | 3D39705G01 | | 1 | 1 | 1 | | | | | 1 | 1 |
| 751 INDICATOR | 1A98827H02 | | | | | | | | | 1 | 1 |
| 275 HART COMMUNICATOR | 275R1EI6B | | | | | | | | | | |
| 115VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G01 | | | | | 1 | | | | | |
| 220VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G02 | | | | | | 1 | | | | |
| 115VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G03 | | | | | | | 1 | | | |
| 220VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G04 | | | | | | | | 1 | | |
| 115VAC/24VDC POWER SUPPLY | 4850B42G01 | | | 1 | | | | | | | 1 |
| 220VAC/24VDC POWER SUPPLY | 4850B42G02 | | | | 1 | | | | | | |

**OPM 2000R –**

**INTELLIGENT ELECTRONICS & OPTIONS**

| | | 22 | 23 | 24 | 25 | 26 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BASIC UNIT (IN BLACK BOX) | 3D39705G01 | 1 | | | | | 1 | 1 | 1 | | |
| 751 INDICATOR | 1A98827H02 | 1 | 1 | 1 | 1 | 1 | | | | | |
| 275 HART COMMUNICATOR | 275R1EI6B | | | | | | 1 | 1 | 1 | 1 | 1 |
| 115VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G01 | | 1 | | | | | | | 1 | |
| 220VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G02 | | | 1 | | | | | | | 1 |
| 115VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G03 | | | | 1 | | | | | | |
| 220VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G04 | | | | | 1 | | | | | |
| 115VAC/24VDC POWER SUPPLY | 4850B42G01 | | | | | | | 1 | | | |
| 220VAC/24VDC POWER SUPPLY | 4850B42G02 | 1 | | | | | | | 1 | | |

**OPM 2000R –**

**INTELLIGENT ELECTRONICS & OPTIONS**

| | | 35 | 36 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|
| BASIC UNIT (IN BLACK BOX) | 3D39705G01 | | | 1 | 1 | 1 | | | | |
| 751 INDICATOR | 1A98827H02 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 275 HART COMMUNICATOR | 275R1EI6B | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 115VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G01 | | | | | | 1 | | | |
| 220VAC/TYPE 4X ENCLOSURE W/P.S. | 3D39704G02 | | | | | | | 1 | | |
| 115VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G03 | 1 | | | | | | | 1 | |
| 220VAC/TYPE 4X ENCL. W/P.S. & HTR. | 3D39704G04 | | 1 | | | | | | | 1 |
| 115VAC/24VDC POWER SUPPLY | 4850B42G01 | | | | 1 | | | | | |
| 220VAC/24VDC POWER SUPPLY | 4850B42G02 | | | | | 1 | | | | |

**OPM 2000R –**

**TRANSCEIVER VOLTAGE**

| | | 00 | 01 | 02 | 03 | 04 |
|---|---|---|---|---|---|---|
| TRANSCEIVER MOUNTING PLATE | | | | | | |
| 110/115V | 3D39703G01 | | 1 | 1 | | |
| 220/240V | 3D39703G02 | | | | 1 | 1 |
| REFLECTOR MTG PLATE | 3D39369G01 | | 1 | 1 | 1 | 1 |
| WEATHER HOUSING | 3D39367G01 | | 2 | 2 | 2 | 2 |
| TRANSCEIVER | | | | | | |
| 100V | 3D39615G02 | | 1 | | | |
| 115V | 3D39615G03 | | | 1 | | |
| 220V | 3D39615G04 | | | | 1 | |
| 240V | 3D39615G05 | | | | | 1 |
| TEST CABLE | 4844B57G01 | | 1 | 1 | 1 | 1 |
| INSTRUCTION BULLETIN | IB 106-200R | | 1 | 1 | 1 | 1 |

## OPM 2000R – ___ ___ ___ ___ ___ ___

**PATHLENGTH LF**

| | | 0 0 | 1 1 | 1 2 | 1 3 | 1 4 |
|---|---|---|---|---|---|---|
| OBJECTIVE LENS | | | | | | |
| 3 - 10 FEET | 4849B57G04 | | 1 | 1 | | |
| 10 - 26 FEET | 4850B48G01 | | | | 1 | 1 |
| INTERNAL REFLECTOR | | | | | | |
| 3 - 5 FEET | 4849B62G03 | | 1 | | 1 | |
| 5 - 10 FEET | 4849B62G02 | | | 1 | | 1 |
| 10 - 20 FEET | 4849B62G06 | | | | 1 | |
| 20 - 26 FEET | 4849B62G05 | | | | | 1 |
| RETROREFLECTOR | | | | | | |
| 3 - 10 FEET | 4846B93G01 | | 1 | 1 | | |
| 10 - 20 FEET | 4846B93G02 | | | | 1 | |
| 20 - 26 FEET | 4846B93G03 | | | | | 1 |

## OPM 2000R – ___ ___ ___ ___ ___ ___

**ZERO JIG**

| | | 0 0 | 0 1 | 0 2 |
|---|---|---|---|---|
| 3 - 20 FEET | 3D39343G01 | | 1 | |
| 20 - 26 FEET | 3D39343G02 | | | 1 |

## OPM 2000R – ___ ___ ___ ___ ___ ___

**CERTIFICATION & LABELING**

| | | 0 0 | 0 1 | 0 2 | 0 3 |
|---|---|---|---|---|---|
| CERT. OF COMPLIANCE | 1A98217 | | 1 | | 1 |
| CSA INSTRUCTIONS | 1A99074 | | | 1 | 1 |
| LABELING KIT | 1A99075G01 | 1 | 1 | | |
| LABELING KIT | 1A99075G02 | | | 1 | 1 |

## OPM 2000R – ___ ___ ___ ___ ___ ___

**ALIGNMENT TUBE**

| | | 0 0 | 0 1 |
|---|---|---|---|
| ALIGNMENT TUBE | 4842B21G01 | | 1 |
| EXTENSION TUBE | 4847B75G01 | | 1 |
| CARRYING CASE | 1A98571H01 | | 1 |
| LABEL | 1A98250H02 | | 1 |

**Table 9-1. Replacement Parts for General Purpose Intelligent Electronics.**

| FIGURE and INDEX NUMBER | PART NUMBER | DESCRIPTION |
|---|---|---|
| 3-1, 6 | 1A99043G01 | IG-1 Software Board |
| 3-1, 15 | 3D39650G01 | HART Daughter Board |
| 3-1, 9 | 1A99032H03 | 6-Pin Plug |
| 3-1, 1 | 1A99032H02 | 4-Pin Plug |
| 3-1, 2 | 1A99032H01 | 3-Pin Plug |
| 3-1, 10 | 1A99032H04 | 9-Pin Plug |

**Table 9-2 Replacement Parts for Type 4X Intelligent Electronics.**

| FIGURE and INDEX NUMBER | PART NUMBER | DESCRIPTION |
|---|---|---|
| 3-5, 15 | 3D39706G01 | Top Cover Plate |
| 3-5, 19 | 1A99043G01 | IG-1 Software Board |
| 3-5, 9 | 3D39650G01 | HART Daughter Board |
| 3-5, 5 | 4850B34G01 | Termination Board |
| 3-5, 7 | 1A99032H05 | 6-Pin Plug |
| 3-5, 17 | 1A99032H06 | 4-Pin Plug |
| 3-5, 18 | 1A99032H07 | 3-Pin Plug |
| 3-5, 8 | 1A99032H04 | 9-Pin Plug |
| 3-5, 21 | 1A98376H02 | Power Supply (24 VDC) |

**Table 9-3. Replacement Parts for Transceiver and Retroreflector Modules.**

| FIGURE and INDEX NUMBER | PART NUMBER | DESCRIPTION |
|---|---|---|
| 2-1, 9 | 3D39367G01 | Weather Housing |
| 2-1, 18 | 4843B11H01 | Filter Retainer |
| 2-1, 20 | 4843B09H02 | Filter (Coarse) |
| 2-1, 21 | 4843B09H01 | Filter (Fine) |
| 2-1, 54 | 1A98502H01 | Purge Air Failure Flow Switch |
| 2-1, 53 | 4842B51G02 | Purge Air Failure Flow Switch Cable (Specify Length) |
| 2-1, 5 | 4511C83H01 | Blower Motor |
| 2-1, 45 through 49 | 9884A16H04 | Filter Assembly for Blower |
| 2-1, 46 | 9884A16H05 | Filter Element |
| 2-1, 58 | 9695D79G06 | Air Lens Assembly |
| 2-1, 61 | 3532B51H01 | Check Valve |

**Table 9-4. Replacement Parts for Transceiver Module.**

| FIGURE and INDEX NUMBER | PART NUMBER | DESCRIPTION |
|---|---|---|
| 2-1 | 3D39702G02 | Transceiver Assembly (100V) |
| 2-1 | 3D39702G03 | Transceiver Assembly (115V) |
| 2-1 | 3D39702G04 | Transceiver Assembly (220V) |
| 2-1 | 3D39702G05 | Transceiver Assembly (240V) |
| 2-1, 34 | 3D39385G01 | Transceiver Mounting Plate |
| 2-2, 50 | 3D39700G01 | Stack LON Board (100V) |
| 2-2, 50 | 3D39700G02 | Stack LON Board (115V) |
| 2-2, 50 | 3D39700G03 | Stack LON Board (220V) |
| 2-2, 50 | 3D39700G04 | Stack LON Board (240V) |
| 2-2, 56 | 3D39317G01 | Detector/Amplifier Board |
| 2-2, 21 | 4846B44G01 | Heater (110/115V) |
| 2-2, 21 | 4846B44G02 | Heater (220/240V) |
| 2-2, 67 | 4841B54H01 | Objective Lens, 3 to 10 ft (0.915 to 3.05 m) |
| 2-2, 67 | 4841B54H02 | Objective Lens, 10 to 26 ft (3.05 to 7.9 m) |
| 6-7 | 3D39343G01 | Zero Jig, 3 to 20 ft (0.915 to 6.1 m) |
| 6-7 | 3D39343G02 | Zero Jig, 20 to 26 ft (6.1 to 7.9 m) |
| 4-9, 4-10 | 3D39664G01 | Stack Termination Board |
| 2-2, 34 | 3D39381G01 | Window Flange (With Zero Jig Locating Pin) |
| 2-2, 17 | 4841B40H01 | Lamp Holder |
| 2-2, 16 | 4841B76H02 | Lamp |
| 2-2, 9 | 4848B50G02 | LCW 1 |
| 2-2, 63 | 4848B50G01 | LCW 2, 3 to 10 ft (0.915 to 3.05 m) |
| 2-2, 63 | 4848B50G03 | LCW 2, 10 to 26 ft (3.05 to 7.9 m) |
| 2-2, 3 through 5, 12, 13 | 4841B10G01 | Beam Splitter Assembly |

**Table 9-5. Replacement Parts for Retroreflector Module.**

| FIGURE and INDEX NUMBER | PART NUMBER | DESCRIPTION |
|---|---|---|
| 5-1 | 3D39369G01 | Retroreflector Mounting Plate (110/115V) |
| 5-1 | 3D39369G02 | Retroreflector Mounting Plate (220/240V) |
| 2-12, 2 | 4846B93G01 | Retroreflector, 3 to 10 ft (0.915 to 3.05 m) |
| 2-12, 2 | 4846B93G02 | Retroreflector, 10 to 20 ft (3.05 to 6.1 m) |
| 2-12, 2 | 4846B93G03 | Retroreflector, 20 to 26 ft (6.1 to 7.9 m) |
| 5-1 | 4842B21G01 | Alignment Sight Assembly |

**Table 9-6. Replacement Parts Kit.**

| FIGURE and INDEX NUMBER | LOCATION | PART NUMBER | DESCRIPTION | QTY IN KIT |
|---|---|---|---|---|
| | | 1A98248G02 | OPM 2000R Spare Parts Kit. Includes the following: | |
| 2-11 | 60 V Power Supply (PS2) Fuse F1 for 100/115 VAC System | 1A97913H12 | Fuse, Slo Blo, 0.1A @ 250 VAC, Case Size: 5 x 20 mm, Cooper Bussman Part No. GMC-100mA | 5 |
| 2-11 | 60 V Power Supply (PS2) Fuse F1 for 220/240 VAC System | 1A97913H17 | Fuse, Slo Blo, 0.063 A @ 250 VAC, Case Size: 5 x 20 mm, Cooper Bussman Part No. GMC-63mA | 5 |
| 2-11 | 5 V, ±15 V Power Supply (PS1) Fuse F2 for 100/115 VAC System | 1A97913H10 | Fuse, Slo Blo, 0.25A @ 250 VAC, Case Size: 5 x 20 mm, Cooper Bussman Part No. GMC-250mA | 5 |
| 2-11 | 5 V, ±15 V Power Supply (PS1) Fuse F2 for 220/240 VAC System | 1A97913H09 | Fuse, Slo Blo, 0.125 A @ 250 VAC, Case Size: 5 x 20 mm, Cooper Bussman Part No. GMC-125mA | 5 |
| 2-11, 3-6, 4-9, and 4-10 | Heater Fuse F3 for 100/115 VAC System, Stack Termination Fuses F1 and F2, and NEMA 4X Intelligent Electronics Fuse F1 | 1A97913H03 | Fuse, Slo Blo, 5 A @ 250 VAC, Case Size: 5 x 20 mm, Schurter Part No. FST 034.3124 | 10 |
| 2-11 | Heater Fuse F3 for 220/240 VAC System | 1A97913H16 | Fuse, Slo Blo, 2.5A @ 250 VAC, Case Size: 5 x 20 mm, Cooper Bussman Part No. GMC-2.5A | 5 |
| 2-1, 21 | Filter Housing | 4843B09H01 | Filter, Fine | 4 |
| 2-1, 20 | Filter Housing | 4843B09H02 | Filter, Coarse | 4 |

**Table 9-7. Certified Neutral Density Filters.**

| | | 4846B98 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | GROUP | | | | | | |
| FILTER DESIGNATION | PART NUMBER | G01 | G02 | G03 | G04 | G05 | G06 | G07 |
| 3% - #503 | 4846B98H01 | 1 | | | | | | |
| 8% - #508 | 4846B98H02 | 1 | | | | | | 1 |
| 20% - #520 | 4846B98H03 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 37% - #537 | 4846B98H04 | | 1 | | | | | 1 |
| 50% - #550 | 4846B98H05 | | 1 | 1 | 1 | | | |
| 60% - #560 | 4846B98H06 | | | 1 | 1 | 1 | | |
| 75% - #575 | 4846B98H07 | | | | 1 | | | |
| 80% - #508 | 4846B98H08 | | | | | 1 | | |
| 88% - #588 | 4846B98H09 | | | | | | 1 | |

# SECTION X. RETURNING EQUIPMENT TO THE FACTORY

**10-1.** If factory repair of defective equipment is required, proceed as follows:

**a.** Secure a return authorization from a Rosemount Analytical Inc. Sales Office or Representative before returning the equipment. Equipment must be returned with complete identification in accordance with Rosemount instructions or it will not be accepted.

In no event will Rosemount be responsible for equipment returned without proper authorization and identification.

**b.** Carefully pack the defective unit in a sturdy box with sufficient shock absorbing material to ensure no additional damage occurs during shipping.

**c.** In a cover letter, describe completely:

1. The symptoms that determined the equipment is faulty.
2. The environment in which the equipment was operating (housing, weather, vibration, dust, etc.).
3. Site from where the equipment was removed.
4. Whether warranty or nonwarranty service is expected.
5. Complete shipping instructions for the return of the equipment.

**d.** Enclose a cover letter and purchase order and ship the defective equipment according to instructions provided in the Rosemount Return Authorization, prepaid, to:

American

Rosemount Analytical Inc.
RMR Department
1201 N. Main Street
Orrville, Ohio 44667

European

Rosemount Analytical Inc.
Equipment Return Repair Dept.
151 Shannon Industrial Estate
Co. Clare
Ireland

If warranty service is expected, the defective unit will be carefully inspected and tested at the factory. If the failure was due to the conditions listed in the standard Rosemount warranty, the defective unit will be repaired or replaced at Rosemount's option, and an operating unit will be returned to the customer in accordance with the shipping instructions furnished in the cover letter.

For equipment no longer under warranty, the equipment will be repaired at the factory and returned as directed by the purchase order and shipping instructions.

# INDEX

This index is an alphabetized listing of parts, terms, and procedures having to do with the OPM 2000R Opacity Transmitter. Every item listed in the index refers to a location in the manual by one or more page numbers.

# APPENDIX A

The following table shows the relationship between percent opacity (Op), percent transmission (Tr), and optical density (OD). Use this chart when performing the EPA filter check procedure in paragraph 6-7.g.

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 100.0 | 0.0000 | 4.7 | 95.3 | 0.0209 | 9.4 | 90.6 | 0.0429 |
| 0.1 | 99.9 | 0.0004 | 4.8 | 95.2 | 0.0214 | 9.5 | 90.5 | 0.0434 |
| 0.2 | 99.8 | 0.0009 | 4.9 | 95.1 | 0.0218 | 9.6 | 90.4 | 0.0438 |
| 0.3 | 99.7 | 0.0013 | 5.0 | 95.0 | 0.0223 | 9.7 | 90.3 | 0.0443 |
| 0.4 | 99.6 | 0.0017 | 5.1 | 94.9 | 0.0227 | 9.8 | 90.2 | 0.0448 |
| 0.5 | 99.5 | 0.0022 | 5.2 | 94.8 | 0.0232 | 9.9 | 90.1 | 0.0453 |
| 0.6 | 99.4 | 0.0026 | 5.3 | 94.7 | 0.0237 | 10.0 | 90.0 | 0.0458 |
| 0.7 | 99.3 | 0.0031 | 5.4 | 94.6 | 0.0241 | 10.1 | 89.9 | 0.0462 |
| 0.8 | 99.2 | 0.0035 | 5.5 | 94.5 | 0.0246 | 10.2 | 89.8 | 0.0467 |
| 0.9 | 99.1 | 0.0039 | 5.6 | 94.4 | 0.0250 | 10.3 | 89.7 | 0.0472 |
| 1.0 | 99.0 | 0.0044 | 5.7 | 94.3 | 0.0255 | 10.4 | 89.6 | 0.0477 |
| 1.1 | 98.9 | 0.0048 | 5.8 | 94.2 | 0.0259 | 10.5 | 89.5 | 0.0482 |
| 1.2 | 98.8 | 0.0052 | 5.9 | 94.1 | 0.0264 | 10.6 | 89.4 | 0.0487 |
| 1.3 | 98.7 | 0.0057 | 6.0 | 94.0 | 0.0269 | 10.7 | 89.3 | 0.0491 |
| 1.4 | 98.6 | 0.0061 | 6.1 | 93.9 | 0.0273 | 10.8 | 89.2 | 0.0496 |
| 1.5 | 98.5 | 0.0066 | 6.2 | 93.8 | 0.0278 | 10.9 | 89.1 | 0.0501 |
| 1.6 | 98.4 | 0.0070 | 6.3 | 93.7 | 0.0283 | 11.0 | 89.0 | 0.0506 |
| 1.7 | 98.3 | 0.0074 | 6.4 | 93.6 | 0.0287 | 11.1 | 88.9 | 0.0511 |
| 1.8 | 98.2 | 0.0079 | 6.5 | 93.5 | 0.0292 | 11.2 | 88.8 | 0.0516 |
| 1.9 | 98.1 | 0.0083 | 6.6 | 93.4 | 0.0297 | 11.3 | 88.7 | 0.0521 |
| 2.0 | 98.0 | 0.0088 | 6.7 | 93.3 | 0.0301 | 11.4 | 88.6 | 0.0526 |
| 2.1 | 97.9 | 0.0092 | 6.8 | 93.2 | 0.0306 | 11.5 | 88.5 | 0.0531 |
| 2.2 | 97.8 | 0.0097 | 6.9 | 93.1 | 0.0311 | 11.6 | 88.4 | 0.0535 |
| 2.3 | 97.7 | 0.0101 | 7.0 | 93.0 | 0.0315 | 11.7 | 88.3 | 0.0540 |
| 2.4 | 97.6 | 0.0106 | 7.1 | 92.9 | 0.0320 | 11.8 | 88.2 | 0.0545 |
| 2.5 | 97.5 | 0.0110 | 7.2 | 92.8 | 0.0325 | 11.9 | 88.1 | 0.0550 |
| 2.6 | 97.4 | 0.0114 | 7.3 | 92.7 | 0.0329 | 12.0 | 88.0 | 0.0555 |
| 2.7 | 97.3 | 0.0119 | 7.4 | 92.6 | 0.0334 | 12.1 | 87.9 | 0.0560 |
| 2.8 | 97.2 | 0.0123 | 7.5 | 92.5 | 0.0339 | 12.2 | 87.8 | 0.0565 |
| 2.9 | 97.1 | 0.0128 | 7.6 | 92.4 | 0.0343 | 12.3 | 87.7 | 0.0570 |
| 3.0 | 97.0 | 0.0132 | 7.7 | 92.3 | 0.0348 | 12.4 | 87.6 | 0.0575 |
| 3.1 | 96.9 | 0.0137 | 7.8 | 92.2 | 0.0353 | 12.5 | 87.5 | 0.0580 |
| 3.2 | 96.8 | 0.0141 | 7.9 | 92.1 | 0.0357 | 12.6 | 87.4 | 0.0585 |
| 3.3 | 96.7 | 0.0146 | 8.0 | 92.0 | 0.0362 | 12.7 | 87.3 | 0.0590 |
| 3.4 | 96.6 | 0.0150 | 8.1 | 91.9 | 0.0367 | 12.8 | 87.2 | 0.0595 |
| 3.5 | 96.5 | 0.0155 | 8.2 | 91.8 | 0.0372 | 12.9 | 87.1 | 0.0600 |
| 3.6 | 96.4 | 0.0159 | 8.3 | 91.7 | 0.0376 | 13.0 | 87.0 | 0.0605 |
| 3.7 | 96.3 | 0.0164 | 8.4 | 91.6 | 0.0381 | 13.1 | 86.9 | 0.0610 |
| 3.8 | 96.2 | 0.0168 | 8.5 | 91.5 | 0.0386 | 13.2 | 86.8 | 0.0615 |
| 3.9 | 96.1 | 0.0173 | 8.6 | 91.4 | 0.0391 | 13.3 | 86.7 | 0.0620 |
| 4.0 | 96.0 | 0.0177 | 8.7 | 91.3 | 0.0395 | 13.4 | 86.6 | 0.0625 |
| 4.1 | 95.9 | 0.0182 | 8.8 | 91.2 | 0.0400 | 13.5 | 86.5 | 0.0630 |
| 4.2 | 95.8 | 0.0186 | 8.9 | 91.1 | 0.0405 | 13.6 | 86.4 | 0.0635 |
| 4.3 | 95.7 | 0.0191 | 9.0 | 91.0 | 0.0410 | 13.7 | 86.3 | 0.0640 |
| 4.4 | 95.6 | 0.0195 | 9.1 | 90.9 | 0.0414 | 13.8 | 86.2 | 0.0645 |
| 4.5 | 95.5 | 0.0200 | 9.2 | 90.8 | 0.0419 | 13.9 | 86.1 | 0.0650 |
| 4.6 | 95.4 | 0.0205 | 9.3 | 90.7 | 0.0424 | 14.0 | 86.0 | 0.0655 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 14.1 | 85.9 | 0.0660 | 18.8 | 81.2 | 0.0904 | 23.5 | 76.5 | 0.1163 |
| 14.2 | 85.8 | 0.0665 | 18.9 | 81.1 | 0.0910 | 23.6 | 76.4 | 0.1169 |
| 14.3 | 85.7 | 0.0670 | 19.0 | 81.0 | 0.0915 | 23.7 | 76.3 | 0.1175 |
| 14.4 | 85.6 | 0.0675 | 19.1 | 80.9 | 0.0921 | 23.8 | 76.2 | 0.1180 |
| 14.5 | 85.5 | 0.0680 | 19.2 | 80.8 | 0.0926 | 23.9 | 76.1 | 0.1186 |
| 14.6 | 85.4 | 0.0685 | 19.3 | 80.7 | 0.0931 | 24.0 | 76.0 | 0.1192 |
| 14.7 | 85.3 | 0.0691 | 19.4 | 80.6 | 0.0937 | 24.1 | 75.9 | 0.1198 |
| 14.8 | 85.2 | 0.0696 | 19.5 | 80.5 | 0.0942 | 24.2 | 75.8 | 0.1203 |
| 14.9 | 85.1 | 0.0701 | 19.6 | 80.4 | 0.0947 | 24.3 | 75.7 | 0.1209 |
| 15.0 | 85.0 | 0.0706 | 19.7 | 80.3 | 0.0953 | 24.4 | 75.6 | 0.1215 |
| 15.1 | 84.9 | 0.0711 | 19.8 | 80.2 | 0.0958 | 24.5 | 75.5 | 0.1221 |
| 15.2 | 84.8 | 0.0716 | 19.9 | 80.1 | 0.0964 | 24.6 | 75.4 | 0.1226 |
| 15.3 | 84.7 | 0.0721 | 20.0 | 80.0 | 0.0969 | 24.7 | 75.3 | 0.1232 |
| 15.4 | 84.6 | 0.0726 | 20.1 | 79.9 | 0.0975 | 24.8 | 75.2 | 0.1238 |
| 15.5 | 84.5 | 0.0731 | 20.2 | 79.8 | 0.0980 | 24.9 | 75.1 | 0.1244 |
| 15.6 | 84.4 | 0.0737 | 20.3 | 79.7 | 0.0985 | 25.0 | 75.0 | 0.1249 |
| 15.7 | 84.3 | 0.0742 | 20.4 | 79.6 | 0.0991 | 25.1 | 74.9 | 0.1255 |
| 15.8 | 84.2 | 0.0747 | 20.5 | 79.5 | 0.0996 | 25.2 | 74.8 | 0.1261 |
| 15.9 | 84.1 | 0.0752 | 20.6 | 79.4 | 0.1002 | 25.3 | 74.7 | 0.1267 |
| 16.0 | 84.0 | 0.0757 | 20.7 | 79.3 | 0.1007 | 25.4 | 74.6 | 0.1273 |
| 16.1 | 83.9 | 0.0762 | 20.8 | 79.2 | 0.1013 | 25.5 | 74.5 | 0.1278 |
| 16.2 | 83.8 | 0.0768 | 20.9 | 79.1 | 0.1018 | 25.6 | 74.4 | 0.1284 |
| 16.3 | 83.7 | 0.0773 | 21.0 | 79.0 | 0.1024 | 25.7 | 74.3 | 0.1290 |
| 16.4 | 83.6 | 0.0778 | 21.1 | 78.9 | 0.1029 | 25.8 | 74.2 | 0.1296 |
| 16.5 | 83.5 | 0.0783 | 21.2 | 78.8 | 0.1035 | 25.9 | 74.1 | 0.1302 |
| 16.6 | 83.4 | 0.0788 | 21.3 | 78.7 | 0.1040 | 26.0 | 74.0 | 0.1308 |
| 16.7 | 83.3 | 0.0794 | 21.4 | 78.6 | 0.1046 | 26.1 | 73.9 | 0.1314 |
| 16.8 | 83.2 | 0.0799 | 21.5 | 78.5 | 0.1051 | 26.2 | 73.8 | 0.1319 |
| 16.9 | 83.1 | 0.0804 | 21.6 | 78.4 | 0.1057 | 26.3 | 73.7 | 0.1325 |
| 17.0 | 83.0 | 0.0809 | 21.7 | 78.3 | 0.1062 | 26.4 | 73.6 | 0.1331 |
| 17.1 | 82.9 | 0.0814 | 21.8 | 78.2 | 0.1068 | 26.5 | 73.5 | 0.1337 |
| 17.2 | 82.8 | 0.0820 | 21.9 | 78.1 | 0.1073 | 26.6 | 73.4 | 0.1343 |
| 17.3 | 82.7 | 0.0825 | 22.0 | 78.0 | 0.1079 | 26.7 | 73.3 | 0.1349 |
| 17.4 | 82.6 | 0.0830 | 22.1 | 77.9 | 0.1085 | 26.8 | 73.2 | 0.1355 |
| 17.5 | 82.5 | 0.0835 | 22.2 | 77.8 | 0.1090 | 26.9 | 73.1 | 0.1361 |
| 17.6 | 82.4 | 0.0841 | 22.3 | 77.7 | 0.1096 | 27.0 | 73.0 | 0.1367 |
| 17.7 | 82.3 | 0.0846 | 22.4 | 77.6 | 0.1101 | 27.1 | 72.9 | 0.1373 |
| 17.8 | 82.2 | 0.0851 | 22.5 | 77.5 | 0.1107 | 27.2 | 72.8 | 0.1379 |
| 17.9 | 82.1 | 0.0857 | 22.6 | 77.4 | 0.1113 | 27.3 | 72.7 | 0.1385 |
| 18.0 | 82.0 | 0.0862 | 22.7 | 77.3 | 0.1118 | 27.4 | 72.6 | 0.1391 |
| 18.1 | 81.9 | 0.0867 | 22.8 | 77.2 | 0.1124 | 27.5 | 72.5 | 0.1397 |
| 18.2 | 81.8 | 0.0872 | 22.9 | 77.1 | 0.1129 | 27.6 | 72.4 | 0.1403 |
| 18.3 | 81.7 | 0.0878 | 23.0 | 77.0 | 0.1135 | 27.7 | 72.3 | 0.1409 |
| 18.4 | 81.6 | 0.0883 | 23.1 | 76.9 | 0.1141 | 27.8 | 72.2 | 0.1415 |
| 18.5 | 81.5 | 0.0888 | 23.2 | 76.8 | 0.1146 | 27.9 | 72.1 | 0.1421 |
| 18.6 | 81.4 | 0.0894 | 23.3 | 76.7 | 0.1152 | 28.0 | 72.0 | 0.1427 |
| 18.7 | 81.3 | 0.0899 | 23.4 | 76.6 | 0.1158 | 28.1 | 71.9 | 0.1433 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 28.2 | 71.8 | 0.1439 | 32.9 | 67.1 | 0.1733 | 37.6 | 62.4 | 0.2048 |
| 28.3 | 71.7 | 0.1445 | 33.0 | 67.0 | 0.1739 | 37.7 | 62.3 | 0.2055 |
| 28.4 | 71.6 | 0.1451 | 33.1 | 66.9 | 0.1746 | 37.8 | 62.2 | 0.2062 |
| 28.5 | 71.5 | 0.1457 | 33.2 | 66.8 | 0.1752 | 37.9 | 62.1 | 0.2069 |
| 28.6 | 71.4 | 0.1463 | 33.3 | 66.7 | 0.1759 | 38.0 | 62.0 | 0.2076 |
| 28.7 | 71.3 | 0.1469 | 33.4 | 66.6 | 0.1765 | 38.1 | 61.9 | 0.2083 |
| 28.8 | 71.2 | 0.1475 | 33.5 | 66.5 | 0.1772 | 38.2 | 61.8 | 0.2090 |
| 28.9 | 71.1 | 0.1481 | 33.6 | 66.4 | 0.1778 | 38.3 | 61.7 | 0.2097 |
| 29.0 | 71.0 | 0.1487 | 33.7 | 66.3 | 0.1785 | 38.4 | 61.6 | 0.2104 |
| 29.1 | 70.9 | 0.1494 | 33.8 | 66.2 | 0.1791 | 38.5 | 61.5 | 0.2111 |
| 29.2 | 70.8 | 0.1500 | 33.9 | 66.1 | 0.1798 | 38.6 | 61.4 | 0.2118 |
| 29.3 | 70.7 | 0.1506 | 34.0 | 66.0 | 0.1805 | 38.7 | 61.3 | 0.2125 |
| 29.4 | 70.6 | 0.1512 | 34.1 | 65.9 | 0.1811 | 38.8 | 61.2 | 0.2132 |
| 29.5 | 70.5 | 0.1518 | 34.2 | 65.8 | 0.1818 | 38.9 | 61.1 | 0.2140 |
| 29.6 | 70.4 | 0.1524 | 34.3 | 65.7 | 0.1824 | 39.0 | 61.0 | 0.2147 |
| 29.7 | 70.3 | 0.1530 | 34.4 | 65.6 | 0.1831 | 39.1 | 60.9 | 0.2154 |
| 29.8 | 70.2 | 0.1537 | 34.5 | 65.5 | 0.1838 | 39.2 | 60.8 | 0.2161 |
| 29.9 | 70.1 | 0.1543 | 34.6 | 65.4 | 0.1844 | 39.3 | 60.7 | 0.2168 |
| 30.0 | 70.0 | 0.1549 | 34.7 | 65.3 | 0.1851 | 39.4 | 60.6 | 0.2175 |
| 30.1 | 69.9 | 0.1555 | 34.8 | 65.2 | 0.1858 | 39.5 | 60.5 | 0.2182 |
| 30.2 | 69.8 | 0.1561 | 34.9 | 65.1 | 0.1864 | 39.6 | 60.4 | 0.2190 |
| 30.3 | 69.7 | 0.1568 | 35.0 | 65.0 | 0.1871 | 39.7 | 60.3 | 0.2197 |
| 30.4 | 69.6 | 0.1574 | 35.1 | 64.9 | 0.1878 | 39.8 | 60.2 | 0.2204 |
| 30.5 | 69.5 | 0.1580 | 35.2 | 64.8 | 0.1884 | 39.9 | 60.1 | 0.2211 |
| 30.6 | 69.4 | 0.1586 | 35.3 | 64.7 | 0.1891 | 40.0 | 60.0 | 0.2218 |
| 30.7 | 69.3 | 0.1593 | 35.4 | 64.6 | 0.1898 | 40.1 | 59.9 | 0.2226 |
| 30.8 | 69.2 | 0.1599 | 35.5 | 64.5 | 0.1904 | 40.2 | 59.8 | 0.2233 |
| 30.9 | 69.1 | 0.1605 | 35.6 | 64.4 | 0.1911 | 40.3 | 59.7 | 0.2240 |
| 31.0 | 69.0 | 0.1612 | 35.7 | 64.3 | 0.1918 | 40.4 | 59.6 | 0.2248 |
| 31.1 | 68.9 | 0.1618 | 35.8 | 64.2 | 0.1925 | 40.5 | 59.5 | 0.2255 |
| 31.2 | 68.8 | 0.1624 | 35.9 | 64.1 | 0.1931 | 40.6 | 59.4 | 0.2262 |
| 31.3 | 68.7 | 0.1630 | 36.0 | 64.0 | 0.1938 | 40.7 | 59.3 | 0.2269 |
| 31.4 | 68.6 | 0.1637 | 36.1 | 63.9 | 0.1945 | 40.8 | 59.2 | 0.2277 |
| 31.5 | 68.5 | 0.1643 | 36.2 | 63.8 | 0.1952 | 40.9 | 59.1 | 0.2284 |
| 31.6 | 68.4 | 0.1649 | 36.3 | 63.7 | 0.1959 | 41.0 | 59.0 | 0.2291 |
| 31.7 | 68.3 | 0.1656 | 36.4 | 63.6 | 0.1965 | 41.1 | 58.9 | 0.2299 |
| 31.8 | 68.2 | 0.1662 | 36.5 | 63.5 | 0.1972 | 41.2 | 58.8 | 0.2306 |
| 31.9 | 68.1 | 0.1669 | 36.6 | 63.4 | 0.1979 | 41.3 | 58.7 | 0.2314 |
| 32.0 | 68.0 | 0.1675 | 36.7 | 63.3 | 0.1986 | 41.4 | 58.6 | 0.2321 |
| 32.1 | 67.9 | 0.1681 | 36.8 | 63.2 | 0.1993 | 41.5 | 58.5 | 0.2328 |
| 32.2 | 67.8 | 0.1688 | 36.9 | 63.1 | 0.2000 | 41.6 | 58.4 | 0.2336 |
| 32.3 | 67.7 | 0.1694 | 37.0 | 63.0 | 0.2007 | 41.7 | 58.3 | 0.2343 |
| 32.4 | 67.6 | 0.1701 | 37.1 | 62.9 | 0.2013 | 41.8 | 58.2 | 0.2351 |
| 32.5 | 67.5 | 0.1707 | 37.2 | 62.8 | 0.2020 | 41.9 | 58.1 | 0.2358 |
| 32.6 | 67.4 | 0.1713 | 37.3 | 62.7 | 0.2027 | 42.0 | 58.0 | 0.2366 |
| 32.7 | 67.3 | 0.1720 | 37.4 | 62.6 | 0.2034 | 42.1 | 57.9 | 0.2373 |
| 32.8 | 67.2 | 0.1726 | 37.5 | 62.5 | 0.2041 | 42.2 | 57.8 | 0.2381 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 42.3 | 57.7 | 0.2388 | 47.0 | 53.0 | 0.2757 | 51.7 | 48.3 | 0.3161 |
| 42.4 | 57.6 | 0.2396 | 47.1 | 52.9 | 0.2765 | 51.8 | 48.2 | 0.3170 |
| 42.5 | 57.5 | 0.2403 | 47.2 | 52.8 | 0.2774 | 51.9 | 48.1 | 0.3179 |
| 42.6 | 57.4 | 0.2411 | 47.3 | 52.7 | 0.2782 | 52.0 | 48.0 | 0.3188 |
| 42.7 | 57.3 | 0.2418 | 47.4 | 52.6 | 0.2790 | 52.1 | 47.9 | 0.3197 |
| 42.8 | 57.2 | 0.2426 | 47.5 | 52.5 | 0.2798 | 52.2 | 47.8 | 0.3206 |
| 42.9 | 57.1 | 0.2434 | 47.6 | 52.4 | 0.2807 | 52.3 | 47.7 | 0.3215 |
| 43.0 | 57.0 | 0.2441 | 47.7 | 52.3 | 0.2815 | 52.4 | 47.6 | 0.3224 |
| 43.1 | 56.9 | 0.2449 | 47.8 | 52.2 | 0.2823 | 52.5 | 47.5 | 0.3233 |
| 43.2 | 56.8 | 0.2457 | 47.9 | 52.1 | 0.2832 | 52.6 | 47.4 | 0.3242 |
| 43.3 | 56.7 | 0.2464 | 48.0 | 52.0 | 0.2840 | 52.7 | 47.3 | 0.3251 |
| 43.4 | 56.6 | 0.2472 | 48.1 | 51.9 | 0.2848 | 52.8 | 47.2 | 0.3261 |
| 43.5 | 56.5 | 0.2480 | 48.2 | 51.8 | 0.2857 | 52.9 | 47.1 | 0.3270 |
| 43.6 | 56.4 | 0.2487 | 48.3 | 51.7 | 0.2865 | 53.0 | 47.0 | 0.3279 |
| 43.7 | 56.3 | 0.2495 | 48.4 | 51.6 | 0.2874 | 53.1 | 46.9 | 0.3288 |
| 43.8 | 56.2 | 0.2503 | 48.5 | 51.5 | 0.2882 | 53.2 | 46.8 | 0.3298 |
| 43.9 | 56.1 | 0.2510 | 48.6 | 51.4 | 0.2890 | 53.3 | 46.7 | 0.3307 |
| 44.0 | 56.0 | 0.2518 | 48.7 | 51.3 | 0.2899 | 53.4 | 46.6 | 0.3316 |
| 44.1 | 55.9 | 0.2526 | 48.8 | 51.2 | 0.2907 | 53.5 | 46.5 | 0.3325 |
| 44.2 | 55.8 | 0.2534 | 48.9 | 51.1 | 0.2916 | 53.6 | 46.4 | 0.3335 |
| 44.3 | 55.7 | 0.2541 | 49.0 | 51.0 | 0.2924 | 53.7 | 46.3 | 0.3344 |
| 44.4 | 55.6 | 0.2549 | 49.1 | 50.9 | 0.2933 | 53.8 | 46.2 | 0.3354 |
| 44.5 | 55.5 | 0.2557 | 49.2 | 50.8 | 0.2941 | 53.9 | 46.1 | 0.3363 |
| 44.6 | 55.4 | 0.2565 | 49.3 | 50.7 | 0.2950 | 54.0 | 46.0 | 0.3372 |
| 44.7 | 55.3 | 0.2573 | 49.4 | 50.6 | 0.2958 | 54.1 | 45.9 | 0.3382 |
| 44.8 | 55.2 | 0.2581 | 49.5 | 50.5 | 0.2967 | 54.2 | 45.8 | 0.3391 |
| 44.9 | 55.1 | 0.2588 | 49.6 | 50.4 | 0.2976 | 54.3 | 45.7 | 0.3401 |
| 45.0 | 55.0 | 0.2596 | 49.7 | 50.3 | 0.2984 | 54.4 | 45.6 | 0.3410 |
| 45.1 | 54.9 | 0.2604 | 49.8 | 50.2 | 0.2993 | 54.5 | 45.5 | 0.3420 |
| 45.2 | 54.8 | 0.2612 | 49.9 | 50.1 | 0.3002 | 54.6 | 45.4 | 0.3429 |
| 45.3 | 54.7 | 0.2620 | 50.0 | 50.0 | 0.3010 | 54.7 | 45.3 | 0.3439 |
| 45.4 | 54.6 | 0.2628 | 50.1 | 49.9 | 0.3019 | 54.8 | 45.2 | 0.3449 |
| 45.5 | 54.5 | 0.2636 | 50.2 | 49.8 | 0.3028 | 54.9 | 45.1 | 0.3458 |
| 45.6 | 54.4 | 0.2644 | 50.3 | 49.7 | 0.3036 | 55.0 | 45.0 | 0.3468 |
| 45.7 | 54.3 | 0.2652 | 50.4 | 49.6 | 0.3045 | 55.1 | 44.9 | 0.3478 |
| 45.8 | 54.2 | 0.2660 | 50.5 | 49.5 | 0.3054 | 55.2 | 44.8 | 0.3487 |
| 45.9 | 54.1 | 0.2668 | 50.6 | 49.4 | 0.3063 | 55.3 | 44.7 | 0.3497 |
| 46.0 | 54.0 | 0.2676 | 50.7 | 49.3 | 0.3072 | 55.4 | 44.6 | 0.3507 |
| 46.1 | 53.9 | 0.2684 | 50.8 | 49.2 | 0.3080 | 55.5 | 44.5 | 0.3516 |
| 46.2 | 53.8 | 0.2692 | 50.9 | 49.1 | 0.3089 | 55.6 | 44.4 | 0.3526 |
| 46.3 | 53.7 | 0.2700 | 51.0 | 49.0 | 0.3098 | 55.7 | 44.3 | 0.3536 |
| 46.4 | 53.6 | 0.2708 | 51.1 | 48.9 | 0.3107 | 55.8 | 44.2 | 0.3546 |
| 46.5 | 53.5 | 0.2716 | 51.2 | 48.8 | 0.3116 | 55.9 | 44.1 | 0.3556 |
| 46.6 | 53.4 | 0.2725 | 51.3 | 48.7 | 0.3125 | 56.0 | 44.0 | 0.3565 |
| 46.7 | 53.3 | 0.2733 | 51.4 | 48.6 | 0.3134 | 56.1 | 43.9 | 0.3575 |
| 46.8 | 53.2 | 0.2741 | 51.5 | 48.5 | 0.3143 | 56.2 | 43.8 | 0.3585 |
| 46.9 | 53.1 | 0.2749 | 51.6 | 48.4 | 0.3152 | 56.3 | 43.7 | 0.3595 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 56.4 | 43.6 | 0.3605 | 61.1 | 38.9 | 0.4101 | 65.8 | 34.2 | 0.4660 |
| 56.5 | 43.5 | 0.3615 | 61.2 | 38.8 | 0.4112 | 65.9 | 34.1 | 0.4672 |
| 56.6 | 43.4 | 0.3625 | 61.3 | 38.7 | 0.4123 | 66.0 | 34.0 | 0.4685 |
| 56.7 | 43.3 | 0.3635 | 61.4 | 38.6 | 0.4134 | 66.1 | 33.9 | 0.4698 |
| 56.8 | 43.2 | 0.3645 | 61.5 | 38.5 | 0.4145 | 66.2 | 33.8 | 0.4711 |
| 56.9 | 43.1 | 0.3655 | 61.6 | 38.4 | 0.4157 | 66.3 | 33.7 | 0.4724 |
| 57.0 | 43.0 | 0.3665 | 61.7 | 38.3 | 0.4168 | 66.4 | 33.6 | 0.4737 |
| 57.1 | 42.9 | 0.3675 | 61.8 | 38.2 | 0.4179 | 66.5 | 33.5 | 0.4750 |
| 57.2 | 42.8 | 0.3686 | 61.9 | 38.1 | 0.4191 | 66.6 | 33.4 | 0.4763 |
| 57.3 | 42.7 | 0.3696 | 62.0 | 38.0 | 0.4202 | 66.7 | 33.3 | 0.4776 |
| 57.4 | 42.6 | 0.3706 | 62.1 | 37.9 | 0.4214 | 66.8 | 33.2 | 0.4789 |
| 57.5 | 42.5 | 0.3716 | 62.2 | 37.8 | 0.4225 | 66.9 | 33.1 | 0.4802 |
| 57.6 | 42.4 | 0.3726 | 62.3 | 37.7 | 0.4237 | 67.0 | 33.0 | 0.4815 |
| 57.7 | 42.3 | 0.3737 | 62.4 | 37.6 | 0.4248 | 67.1 | 32.9 | 0.4828 |
| 57.8 | 42.2 | 0.3747 | 62.5 | 37.5 | 0.4260 | 67.2 | 32.8 | 0.4841 |
| 57.9 | 42.1 | 0.3757 | 62.6 | 37.4 | 0.4271 | 67.3 | 32.7 | 0.4855 |
| 58.0 | 42.0 | 0.3768 | 62.7 | 37.3 | 0.4283 | 67.4 | 32.6 | 0.4868 |
| 58.1 | 41.9 | 0.3778 | 62.8 | 37.2 | 0.4295 | 67.5 | 32.5 | 0.4881 |
| 58.2 | 41.8 | 0.3788 | 62.9 | 37.1 | 0.4306 | 67.6 | 32.4 | 0.4895 |
| 58.3 | 41.7 | 0.3799 | 63.0 | 37.0 | 0.4318 | 67.7 | 32.3 | 0.4908 |
| 58.4 | 41.6 | 0.3809 | 63.1 | 36.9 | 0.4330 | 67.8 | 32.2 | 0.4921 |
| 58.5 | 41.5 | 0.3820 | 63.2 | 36.8 | 0.4342 | 67.9 | 32.1 | 0.4935 |
| 58.6 | 41.4 | 0.3830 | 63.3 | 36.7 | 0.4353 | 68.0 | 32.0 | 0.4949 |
| 58.7 | 41.3 | 0.3840 | 63.4 | 36.6 | 0.4365 | 68.1 | 31.9 | 0.4962 |
| 58.8 | 41.2 | 0.3851 | 63.5 | 36.5 | 0.4377 | 68.2 | 31.8 | 0.4976 |
| 58.9 | 41.1 | 0.3862 | 63.6 | 36.4 | 0.4389 | 68.3 | 31.7 | 0.4989 |
| 59.0 | 41.0 | 0.3872 | 63.7 | 36.3 | 0.4401 | 68.4 | 31.6 | 0.5003 |
| 59.1 | 40.9 | 0.3883 | 63.8 | 36.2 | 0.4413 | 68.5 | 31.5 | 0.5017 |
| 59.2 | 40.8 | 0.3893 | 63.9 | 36.1 | 0.4425 | 68.6 | 31.4 | 0.5031 |
| 59.3 | 40.7 | 0.3904 | 64.0 | 36.0 | 0.4437 | 68.7 | 31.3 | 0.5045 |
| 59.4 | 40.6 | 0.3915 | 64.1 | 35.9 | 0.4449 | 68.8 | 31.2 | 0.5058 |
| 59.5 | 40.5 | 0.3925 | 64.2 | 35.8 | 0.4461 | 68.9 | 31.1 | 0.5072 |
| 59.6 | 40.4 | 0.3936 | 64.3 | 35.7 | 0.4473 | 69.0 | 31.0 | 0.5086 |
| 59.7 | 40.3 | 0.3947 | 64.4 | 35.6 | 0.4486 | 69.1 | 30.9 | 0.5100 |
| 59.8 | 40.2 | 0.3958 | 64.5 | 35.5 | 0.4498 | 69.2 | 30.8 | 0.5114 |
| 59.9 | 40.1 | 0.3969 | 64.6 | 35.4 | 0.4510 | 69.3 | 30.7 | 0.5129 |
| 60.0 | 40.0 | 0.3979 | 64.7 | 35.3 | 0.4522 | 69.4 | 30.6 | 0.5143 |
| 60.1 | 39.9 | 0.3990 | 64.8 | 35.2 | 0.4535 | 69.5 | 30.5 | 0.5157 |
| 60.2 | 39.8 | 0.4001 | 64.9 | 35.1 | 0.4547 | 69.6 | 30.4 | 0.5171 |
| 60.3 | 39.7 | 0.4012 | 65.0 | 35.0 | 0.4559 | 69.7 | 30.3 | 0.5186 |
| 60.4 | 39.6 | 0.4023 | 65.1 | 34.9 | 0.4572 | 69.8 | 30.2 | 0.5200 |
| 60.5 | 39.5 | 0.4034 | 65.2 | 34.8 | 0.4584 | 69.9 | 30.1 | 0.5214 |
| 60.6 | 39.4 | 0.4045 | 65.3 | 34.7 | 0.4597 | 70.0 | 30.0 | 0.5229 |
| 60.7 | 39.3 | 0.4056 | 65.4 | 34.6 | 0.4609 | 70.1 | 29.9 | 0.5243 |
| 60.8 | 39.2 | 0.4067 | 65.5 | 34.5 | 0.4622 | 70.2 | 29.8 | 0.5258 |
| 60.9 | 39.1 | 0.4078 | 65.6 | 34.4 | 0.4634 | 70.3 | 29.7 | 0.5272 |
| 61.0 | 39.0 | 0.4089 | 65.7 | 34.3 | 0.4647 | 70.4 | 29.6 | 0.5287 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 70.5 | 29.5 | 0.5302 | 75.2 | 24.8 | 0.6055 | 79.9 | 20.1 | 0.6968 |
| 70.6 | 29.4 | 0.5317 | 75.3 | 24.7 | 0.6073 | 80.0 | 20.0 | 0.6990 |
| 70.7 | 29.3 | 0.5331 | 75.4 | 24.6 | 0.6091 | 80.1 | 19.9 | 0.7011 |
| 70.8 | 29.2 | 0.5346 | 75.5 | 24.5 | 0.6108 | 80.2 | 19.8 | 0.7033 |
| 70.9 | 29.1 | 0.5361 | 75.6 | 24.4 | 0.6126 | 80.3 | 19.7 | 0.7055 |
| 71.0 | 29.0 | 0.5376 | 75.7 | 24.3 | 0.6144 | 80.4 | 19.6 | 0.7077 |
| 71.1 | 28.9 | 0.5391 | 75.8 | 24.2 | 0.6162 | 80.5 | 19.5 | 0.7100 |
| 71.2 | 28.8 | 0.5406 | 75.9 | 24.1 | 0.6180 | 80.6 | 19.4 | 0.7122 |
| 71.3 | 28.7 | 0.5421 | 76.0 | 24.0 | 0.6198 | 80.7 | 19.3 | 0.7144 |
| 71.4 | 28.6 | 0.5436 | 76.1 | 23.9 | 0.6216 | 80.8 | 19.2 | 0.7167 |
| 71.5 | 28.5 | 0.5452 | 76.2 | 23.8 | 0.6234 | 80.9 | 19.1 | 0.7190 |
| 71.6 | 28.4 | 0.5467 | 76.3 | 23.7 | 0.6253 | 81.0 | 19.0 | 0.7212 |
| 71.7 | 28.3 | 0.5482 | 76.4 | 23.6 | 0.6271 | 81.1 | 18.9 | 0.7235 |
| 71.8 | 28.2 | 0.5498 | 76.5 | 23.5 | 0.6289 | 81.2 | 18.8 | 0.7258 |
| 71.9 | 28.1 | 0.5513 | 76.6 | 23.4 | 0.6308 | 81.3 | 18.7 | 0.7282 |
| 72.0 | 28.0 | 0.5528 | 76.7 | 23.3 | 0.6326 | 81.4 | 18.6 | 0.7305 |
| 72.1 | 27.9 | 0.5544 | 76.8 | 23.2 | 0.6345 | 81.5 | 18.5 | 0.7328 |
| 72.2 | 27.8 | 0.5560 | 76.9 | 23.1 | 0.6364 | 81.6 | 18.4 | 0.7352 |
| 72.3 | 27.7 | 0.5575 | 77.0 | 23.0 | 0.6383 | 81.7 | 18.3 | 0.7375 |
| 72.4 | 27.6 | 0.5591 | 77.1 | 22.9 | 0.6402 | 81.8 | 18.2 | 0.7399 |
| 72.5 | 27.5 | 0.5607 | 77.2 | 22.8 | 0.6421 | 81.9 | 18.1 | 0.7423 |
| 72.6 | 27.4 | 0.5622 | 77.3 | 22.7 | 0.6440 | 82.0 | 18.0 | 0.7447 |
| 72.7 | 27.3 | 0.5638 | 77.4 | 22.6 | 0.6459 | 82.1 | 17.9 | 0.7471 |
| 72.8 | 27.2 | 0.5654 | 77.5 | 22.5 | 0.6478 | 82.2 | 17.8 | 0.7496 |
| 72.9 | 27.1 | 0.5670 | 77.6 | 22.4 | 0.6498 | 82.3 | 17.7 | 0.7520 |
| 73.0 | 27.0 | 0.5686 | 77.7 | 22.3 | 0.6517 | 82.4 | 17.6 | 0.7545 |
| 73.1 | 26.9 | 0.5702 | 77.8 | 22.2 | 0.6536 | 82.5 | 17.5 | 0.7570 |
| 73.2 | 26.8 | 0.5719 | 77.9 | 22.1 | 0.6556 | 82.6 | 17.4 | 0.7595 |
| 73.3 | 26.7 | 0.5735 | 78.0 | 22.0 | 0.6576 | 82.7 | 17.3 | 0.7620 |
| 73.4 | 26.6 | 0.5751 | 78.1 | 21.9 | 0.6596 | 82.8 | 17.2 | 0.7645 |
| 73.5 | 26.5 | 0.5768 | 78.2 | 21.8 | 0.6615 | 82.9 | 17.1 | 0.7670 |
| 73.6 | 26.4 | 0.5784 | 78.3 | 21.7 | 0.6635 | 83.0 | 17.0 | 0.7696 |
| 73.7 | 26.3 | 0.5800 | 78.4 | 21.6 | 0.6655 | 83.1 | 16.9 | 0.7721 |
| 73.8 | 26.2 | 0.5817 | 78.5 | 21.5 | 0.6676 | 83.2 | 16.8 | 0.7747 |
| 73.9 | 26.1 | 0.5834 | 78.6 | 21.4 | 0.6696 | 83.3 | 16.7 | 0.7773 |
| 74.0 | 26.0 | 0.5850 | 78.7 | 21.3 | 0.6716 | 83.4 | 16.6 | 0.7799 |
| 74.1 | 25.9 | 0.5867 | 78.8 | 21.2 | 0.6737 | 83.5 | 16.5 | 0.7825 |
| 74.2 | 25.8 | 0.5884 | 78.9 | 21.1 | 0.6757 | 83.6 | 16.4 | 0.7852 |
| 74.3 | 25.7 | 0.5901 | 79.0 | 21.0 | 0.6778 | 83.7 | 16.3 | 0.7878 |
| 74.4 | 25.6 | 0.5918 | 79.1 | 20.9 | 0.6799 | 83.8 | 16.2 | 0.7905 |
| 74.5 | 25.5 | 0.5935 | 79.2 | 20.8 | 0.6819 | 83.9 | 16.1 | 0.7932 |
| 74.6 | 25.4 | 0.5952 | 79.3 | 20.7 | 0.6840 | 84.0 | 16.0 | 0.7959 |
| 74.7 | 25.3 | 0.5969 | 79.4 | 20.6 | 0.6861 | 84.1 | 15.9 | 0.7986 |
| 74.8 | 25.2 | 0.5986 | 79.5 | 20.5 | 0.6882 | 84.2 | 15.8 | 0.8013 |
| 74.9 | 25.1 | 0.6003 | 79.6 | 20.4 | 0.6904 | 84.3 | 15.7 | 0.8041 |
| 75.0 | 25.0 | 0.6021 | 79.7 | 20.3 | 0.6925 | 84.4 | 15.6 | 0.8069 |
| 75.1 | 24.9 | 0.6038 | 79.8 | 20.2 | 0.6946 | 84.5 | 15.5 | 0.8097 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 84.6 | 15.4 | 0.8125 | 89.3 | 10.7 | 0.9706 | 94.0 | 6.0 | 1.2218 |
| 84.7 | 15.3 | 0.8153 | 89.4 | 10.6 | 0.9747 | 94.1 | 5.9 | 1.2291 |
| 84.8 | 15.2 | 0.8182 | 89.5 | 10.5 | 0.9788 | 94.2 | 5.8 | 1.2366 |
| 84.9 | 15.1 | 0.8210 | 89.6 | 10.4 | 0.9830 | 94.3 | 5.7 | 1.2441 |
| 85.0 | 15.0 | 0.8239 | 89.7 | 10.3 | 0.9872 | 94.4 | 5.6 | 1.2518 |
| 85.1 | 14.9 | 0.8268 | 89.8 | 10.2 | 0.9914 | 94.5 | 5.5 | 1.2596 |
| 85.2 | 14.8 | 0.8297 | 89.9 | 10.1 | 0.9957 | 94.6 | 5.4 | 1.2676 |
| 85.3 | 14.7 | 0.8327 | 90.0 | 10.0 | 1.0000 | 94.7 | 5.3 | 1.2757 |
| 85.4 | 14.6 | 0.8356 | 90.1 | 9.9 | 1.0044 | 94.8 | 5.2 | 1.2840 |
| 85.5 | 14.5 | 0.8386 | 90.2 | 9.8 | 1.0088 | 94.9 | 5.1 | 1.2924 |
| 85.6 | 14.4 | 0.8416 | 90.3 | 9.7 | 1.0132 | 95.0 | 5.0 | 1.3010 |
| 85.7 | 14.3 | 0.8447 | 90.4 | 9.6 | 1.0177 | 95.1 | 4.9 | 1.3098 |
| 85.8 | 14.2 | 0.8477 | 90.5 | 9.5 | 1.0223 | 95.2 | 4.8 | 1.3188 |
| 85.9 | 14.1 | 0.8508 | 90.6 | 9.4 | 1.0269 | 95.3 | 4.7 | 1.3279 |
| 86.0 | 14.0 | 0.8539 | 90.7 | 9.3 | 1.0315 | 95.4 | 4.6 | 1.3372 |
| 86.1 | 13.9 | 0.8570 | 90.8 | 9.2 | 1.0362 | 95.5 | 4.5 | 1.3468 |
| 86.2 | 13.8 | 0.8601 | 90.9 | 9.1 | 1.0410 | 95.6 | 4.4 | 1.3565 |
| 86.3 | 13.7 | 0.8633 | 91.0 | 9.0 | 1.0458 | 95.7 | 4.3 | 1.3665 |
| 86.4 | 13.6 | 0.8665 | 91.1 | 8.9 | 1.0506 | 95.8 | 4.2 | 1.3768 |
| 86.5 | 13.5 | 0.8697 | 91.2 | 8.8 | 1.0555 | 95.9 | 4.1 | 1.3872 |
| 86.6 | 13.4 | 0.8729 | 91.3 | 8.7 | 1.0605 | 96.0 | 4.0 | 1.3979 |
| 86.7 | 13.3 | 0.8761 | 91.4 | 8.6 | 1.0655 | 96.1 | 3.9 | 1.4089 |
| 86.8 | 13.2 | 0.8794 | 91.5 | 8.5 | 1.0706 | 96.2 | 3.8 | 1.4202 |
| 86.9 | 13.1 | 0.8827 | 91.6 | 8.4 | 1.0757 | 96.3 | 3.7 | 1.4318 |
| 87.0 | 13.0 | 0.8861 | 91.7 | 8.3 | 1.0809 | 96.4 | 3.6 | 1.4437 |
| 87.1 | 12.9 | 0.8894 | 91.8 | 8.2 | 1.0862 | 96.5 | 3.5 | 1.4559 |
| 87.2 | 12.8 | 0.8928 | 91.9 | 8.1 | 1.0915 | 96.6 | 3.4 | 1.4685 |
| 87.3 | 12.7 | 0.8962 | 92.0 | 8.0 | 1.0969 | 96.7 | 3.3 | 1.4815 |
| 87.4 | 12.6 | 0.8996 | 92.1 | 7.9 | 1.1024 | 96.8 | 3.2 | 1.4949 |
| 87.5 | 12.5 | 0.9031 | 92.2 | 7.8 | 1.1079 | 96.9 | 3.1 | 1.5086 |
| 87.6 | 12.4 | 0.9066 | 92.3 | 7.7 | 1.1135 | 97.0 | 3.0 | 1.5229 |
| 87.7 | 12.3 | 0.9101 | 92.4 | 7.6 | 1.1192 | 97.1 | 2.9 | 1.5376 |
| 87.8 | 12.2 | 0.9136 | 92.5 | 7.5 | 1.1249 | 97.2 | 2.8 | 1.5528 |
| 87.9 | 12.1 | 0.9172 | 92.6 | 7.4 | 1.1308 | 97.3 | 2.7 | 1.5686 |
| 88.0 | 12.0 | 0.9208 | 92.7 | 7.3 | 1.1367 | 97.4 | 2.6 | 1.5850 |
| 88.1 | 11.9 | 0.9245 | 92.8 | 7.2 | 1.1427 | 97.5 | 2.5 | 1.6021 |
| 88.2 | 11.8 | 0.9281 | 92.9 | 7.1 | 1.1487 | 97.6 | 2.4 | 1.6198 |
| 88.3 | 11.7 | 0.9318 | 93.0 | 7.0 | 1.1549 | 97.7 | 2.3 | 1.6383 |
| 88.4 | 11.6 | 0.9355 | 93.1 | 6.9 | 1.1612 | 97.8 | 2.2 | 1.6576 |
| 88.5 | 11.5 | 0.9393 | 93.2 | 6.8 | 1.1675 | 97.9 | 2.1 | 1.6778 |
| 88.6 | 11.4 | 0.9431 | 93.3 | 6.7 | 1.1739 | 98.0 | 2.0 | 1.6990 |
| 88.7 | 11.3 | 0.9469 | 93.4 | 6.6 | 1.1805 | 98.1 | 1.9 | 1.7212 |
| 88.8 | 11.2 | 0.9508 | 93.5 | 6.5 | 1.1871 | 98.2 | 1.8 | 1.7447 |
| 88.9 | 11.1 | 0.9547 | 93.6 | 6.4 | 1.1938 | 98.3 | 1.7 | 1.7696 |
| 89.0 | 11.0 | 0.9586 | 93.7 | 6.3 | 1.2007 | 98.4 | 1.6 | 1.7959 |
| 89.1 | 10.9 | 0.9626 | 93.8 | 6.2 | 1.2076 | 98.5 | 1.5 | 1.8239 |
| 89.2 | 10.8 | 0.9666 | 93.9 | 6.1 | 1.2147 | 98.6 | 1.4 | 1.8539 |

| Op | Tr | Density | Op | Tr | Density | Op | Tr | Density |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 98.7 | 1.3 | 1.8861 | 99.2 | 0.8 | 2.0969 | 99.6 | 0.4 | 2.3979 |
| 98.8 | 1.2 | 1.9208 | 99.3 | 0.7 | 2.1549 | 99.7 | 0.3 | 2.5229 |
| 98.9 | 1.1 | 1.9586 | 99.4 | 0.6 | 2.2218 | 99.8 | 0.2 | 2.6990 |
| 99.0 | 1.0 | 2.0000 | 99.5 | 0.5 | 2.3010 | 99.9 | 0.1 | 3.0000 |
| 99.1 | 0.9 | 2.0458 | | | | | | |

# APPENDIX B

The following chart is the preventive maintenance schedule for ensuring maximum uptime of your OPM 2000R Opacity Transmitter. The checklist is to serve as a guideline for performing preventive maintenance. At a minimum, perform all maintenance at the specified intervals. Certain situations may require more frequent checks and service. Refer to Sections VI and VIII for calibration, disassembly, assembly, and replacement procedures.

## OPM 2000R SERVICE SCHEDULE

**A - QUARTERLY AUDIT**
**C - CLEAN**
**T - RETURN FOR RE-CERTIFICATION**
**I - INSPECT After inspection, clean, lubricate, adjust or replace if necessary**
**R - REPLACE**

| | MONTHS | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AIR LENS ASSEMBLY | | | | C | | | | C | | | | C | | | | C |
| | AIR LENS SEAL PLATE | | | | I | | | | I | | | | I | | | | I |
| | ALIGN OPTICS | | | | I | | | | I | | | | I | | | | I |
| | BEAM SPLITTER | | | | I | | | | I | | | | I | | | | I |
| | BLOWERS | | I | | I | | I | | I | | I | | I | | I | | I |
| | CHECK VALVE | | | | I | | | | I | | | | I | | | | I |
| | CORNER CUBE RETROREFLECTOR | | C | | C | | C | | C | | C | | C | | C | | C |
| | DETECTOR/AMPLIFIER BOARD | | | | I | | | | I | | | | I | | | | I |
| | EPA AUDIT/FILTER CHECK | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| ⌘ | FILTER ELEMENTS INTERNAL | | C | | C | | C | | C | | C | | C | | C | | R |
| ⌘ | FILTERS FINE, COARSE, EXTERNAL | C | C | C | C | C | C | C | R | C | C | C | C | C | C | C | R |
| | HEATER (OPTICAL BENCH) | | | | I | | | | I | | | | I | | | | I |
| | INTELLIGENT ELECTRONICS | | | | | | | | | | | | | | | | |
| | INTERNAL RETROREFLECTOR | | | | I | | | | I | | | | I | | | | I |
| | LAMP REPLACEMENT | | | | | | | | I | | | | | | | | I |
| | LIQUID CRYSTAL WINDOWS | | | | | | | | I | | | | | | | | I |
| | NEUTRAL DENSITY FILTERS | | | | T | | | | T | | | | T | | | | T |
| | OBJECTIVE LENS | | | | I | | | | C | | | | I | | | | C |
| | OFFLINE CALIBRATE | | | | I | | | | I | | | | I | | | | I |
| | OPTICAL ALIGNMENT | | | | I | | | | I | | | | I | | | | I |
| | TRANSCEIVER POWER SUPPLY 1 | | | | I | | | | I | | | | I | | | | I |
| | TRANSCEIVER POWER SUPPLY 2 | | | | I | | | | I | | | | I | | | | I |
| | TRANSCEIVER STACK LON BOARD | | | | I | | | | I | | | | I | | | | I |
| | PURGE AIR FAILURE FLOW SWITCH | | | | I | | | | I | | | | I | | | | I |
| | TRANSCEIVER WINDOW | | C | | C | | C | | C | | C | | C | | C | | C |
| | WEATHER HOUSING | | | | I | | | | I | | | | I | | | | I |
| | ZERO JIG | | | | I | | | | I | | | | I | | | | I |
| | ZERO AND SPAN CHECK | | | | | | | | | | | | | | | | |

⌘ **Under severe ambient conditions, service these items more frequently.**

# APPENDIX C

Use this worksheet to record and reference the settings of your OPM 2000R system.

## ROSEMOUNT OPACITY VALUES WORKSHEET

Unit Serial Number: _____
P.O. Number: _____
Date: _____

| MENU | ACCESS | PARAMETER | | READING |
|---|---|---|---|---|
| PROCESS VARIABLES | Fld Device Volts | Vstack | | |
| | | Vlamp | | |
| | | Vamb | | |
| | | Vdark | | |
| | | Stack Temperature | Vad 590 | |
| | | | Temp | |
| | Output Variables | PV Output Vars | PV is | |
| | | | Opacity Value | |
| | | | % Rnge | |
| | | | PV AO (Opacity Output) | |
| | | SV Output Vars | SV is | |
| | | | Opacity Value | |
| | | | % Rnge | |
| | | | SV AO (Opacity Output) | |
| | | TV Output Vars | TV is | |
| | | | Opacity Value | |
| | | | % Rnge | |
| | | | TV AO (Opacity Output) | |
| | Variable Mapping | Variable Mapping | | |
| | Variable Re-map | Variable Re-map Method | | |
| DIAGNOSTIC/ SERVICE | Status | Status Group 0 | LON COM Status | |
| | | | AO1 DAC Trim | |
| | | Status Group 1 | Blower Failure | |
| | | | Chk Optics Mode | |
| | | | TCVR Cal Status | |
| | | | Dter too High | |
| | | | Lamp Status | |
| | | Status Group 2 | Heater Status | |
| | | | PR SW #1 Status | |
| | | | LP Button Status | |
| | | | PR SW #2 Status | |
| | | | Vlamp too High | |
| | | | DIG IN Status | |

| MENU | ACCESS | PARAMETER | | READING |
|---|---|---|---|---|
| DIAGNOSTIC/ SERVICE (Cont.) | Status (Cont.) | Status Group 3 | Relay 1 | |
| | | | Relay 2 | |
| | | | Relay 3 | |
| | | | Relay 4 | |
| | | | Relay 5 | |
| | | | Relay 6 | |
| | | AO Saturated | AO1 | |
| | | | AO2 | |
| | | | AO3 | |
| | | AO Fixed | AO1 | |
| | | | AO2 | |
| | | | AO3 | |
| | Offline Cal | Offline Cal Method | | |
| | Ref. Voltages | CalDate | | |
| | | CalTime | | |
| | | Vstack0 | | |
| | | Vlamp0 | | |
| | | Vamb0 | | |
| | | Vdark0 | | |
| | | Vstack1 | | |
| | | Vlamp1 | | |
| | | Vamb1 | | |
| | | Vdark1 | | |
| | | OCRF | | |
| | Trim DAC | Trim DAC Method | | |
| | Loop Test | Loop Test PV | Loop Test PV Method | |
| | | Loop Test SV | Loop Test SV Method | |
| | | Loop Test TV | Loop Test TV Method | |
| | Check Optics | Check Optics Method | | |
| | Fltr Chk | Filter Check | Filter Check Method | |
| | | Fltr Chk Values | Fltr Chk Values Method | |
| | | Erase Fltr Values | Erase Fltr Values Method | |
| BASIC SETUP | Setup Clock | Date | | |
| | | Time | | |
| | | Clock Setup | Clock Setup Method | |
| | Range Values | Select PV Range | URV \| URV Method | |
| | | | LRV | |
| | | Select SV Range | URV \| URV Method | |
| | | | LRV | |
| | | Select TV Range | URV \| URV Method | |
| | | | LRV | |
| | LX/LT | Lx/Lt | | |
| | | LX/LT Setup | Lx/Lt Setup Method | |

| MENU | ACCESS | PARAMETER | | READING |
|---|---|---|---|---|
| BASIC SETUP (Cont.) | Device Info | Dev ID | | |
| | | Descriptor | | |
| | | Tag | | |
| | | Message | | |
| DETAILED SETUP | Relay Config | Relay Config | Relay Config Method | |
| | | Relay 1 | | |
| | | Relay 2 | | |
| | | Relay 3 | | |
| | | Relay 4 | | |
| | | Relay 5 | | |
| | | Relay 6 | | |
| | Zero/Span Check | Zero Val | | |
| | | Zero Fltr | | |
| | | Span Val | | |
| | | Span Fltr | | |
| | | Period | | |
| | | Start | | |
| | | Zero Dur | | |
| | | Span Dur | | |
| | | Zero/Span Configuration | Zero/Span Configuration Method | |
| | Averages | Average 1 | Avg 1 Var | |
| | | | Avg 1 Per | |
| | | Average 2 | Avg 2 Var | |
| | | | Avg 2 Per | |
| | Alarms | Alarm Config | Alarm Config Method | |
| | | Alarm 1 | | |
| | | Alarm 1 Type | | |
| | | AL1 Setpoint | | |
| | | AL1 Deadband | | |
| | | Alarm 2 | | |
| | | Alarm 2 Type | | |
| | | AL2 Setpoint | | |
| | | AL2 Deadband | | |
| | Dust Setup | Dust C | | |
| | | Dust K | | |
| | | Date | | |
| | | Time | | |
| | | Dust Configuration | Dust Configuration Method | |

| MENU | ACCESS | PARAMETER | READING |
|---|---|---|---|
| REVIEW | IG-1 S/W Version | Rev Num | |
| | | Rev Year | |
| | | Rev Month | |
| | | Rev Day | |
| | | Rev Hour | |
| | | Rev Minute | |
| | Stack S/W Version | Rev Num | |
| | | Rev Year | |
| | | Rev Month | |
| | | Rev Day | |
| | | Rev Hour | |
| | | Rev Minute | |
| | Serial Numbers | System SN | |