Modified Leachate and Condensate Vapor Sampling Protocol Chiquita Canyon Landfill

Chiquita Canyon Landfill
29201 Henry Mayo Drive
Castaic, California 91384

SCS ENGINEERS

01204123.21 Task 22 | June 2026

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This Modified Leachate and Condensate Vapor Sampling Protocol (VSP) for the Chiquita Canyon Landfill, located at 29201 Henry Mayo Drive, Castaic, California, was prepared and reviewed by the following:

Patrick S. Sullivan, REPA, CPP, BCES
Senior Vice President
SCS ENGINEERS

1.0 INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

This document serves as a Modified Leachate and Condensate Vapor Sampling Protocol (VSP) for the Chiquita Canyon Landfill (Landfill or Site), prepared by SCS Engineers (SCS) in collaboration with Chiquita Canyon, LLC (CCL), and in compliance with Condition 72 of the Modified Stipulated Order for Abatement (SOFA) issued to Chiquita by the South Coast Air Quality Management District (SCAQMD) on April 24, 2024, most recently modified on June 3, 2026.

The goal of this VSP is to provide details regarding the sample collection locations, sample collection methods, frequency of sampling, analytical methods to be utilized, and data reporting requirements as specified in Condition 72(a) and (b). This VSP will be revised over time based on the identification of additional sampling locations, field verification of sampling locations, and potentially sampling method modifications for improvement of sample collection, as needed.

1.2 BACKGROUND

The following provides Condition 72(a)–(b) of the SOFA:

> *72. Respondent shall conduct sampling and analysis, testing, installation, and monitoring of the leachate and landfill gas condensate collection, storage, and treatment tank system, as specified below:*
>
> *a. At least semi-annually, conduct testing to sample and analyze the vapor flow in the piping used to vent the leachate storage/treatment tanks and landfill gas condensate storage/treatment tanks and route the vapors to the landfill gas control system, and the landfill gas header line(s) feeding the flares/thermal oxidizers. The testing shall at least include the following items, and the results of this testing shall be provided in the monthly report pursuant to Condition No. 8.:*
>
> *i. vented leachate tank vapor flowrate,*
>
> *ii. vented condensate tank vapor flowrate,*
>
> *iii. vapor temperature,*
>
> *iv. concentrations of speciated organics (including but not limited to Rule 1150.1 Table 1 Carcinogenic and Toxic Air Contaminants),*
>
> *v. the total sulfur compounds as H2S and speciated sulfur compounds, and*
>
> *vi. testing at each of the locations indicated below:*
>
> *1. The tank vents or manifolds which are representative of a set of tanks;*

2. *The header/manifold from each leachate tank farm or manifold including Tank Farm #7, Tank Farm #9, North Perimeter Manifold, New East Perimeter Manifold, LC Manifold, landfill gas condensate storage tanks, and any other future tank farms or manifolds, with testing performed upstream of the piping connection to the LFG Collection and Conveyance System where landfill gas may affect results; and*

3. *The inlet of the flare(s)/thermal oxidizers prior to combustion.*

4. *The landfill gas header line(s) to the flares/thermal oxidizers (upstream of leachate/condensate vapor mixing)*

vii. *gas heat rating (BTU/scf)*

viii. *Landfill gas vapor flowrate*

b. *A modified source test protocol for this testing shall be submitted to South Coast AQMD by June 30, 2026, unless otherwise approved in writing by South Coast AQMD. Testing shall be conducted within 45 days of receiving written approval of the source test protocol by South Coast AQMD, and the final results in a source test report format shall be submitted within 30 days of testing, unless otherwise approved in writing by South Coast AQMD.*

2.0 SAMPLING METHODS AND TEST PARAMETERS

Condition 72(a) requires that the following parameters are measured and/or analyzed from the leachate and condensate vapor collection system at various locations within the piping network from the liquid tanks to the landfill gas (LFG) system and prior to injection into LFG flares:

- Vented Leachate Tank Vapor Flowrate as Applicable
- Vented Condensate Tank Vapor Flowrate as Applicable
- Vapor Temperature
- Analysis for Speciated Organics as Identified in Rule 1150.1 Table 1 Carcinogenic and Toxic Air Contaminants
- Total Sulfur Compounds as Hydrogen Sulfide (H2S) and speciated sulfur compounds
- Gas Heat Rating ((British Thermal Units per standard cubic foot (BTU/scf))
- LFG Vapor Flow Rate.

Sampling ports will be installed at each of the sampling locations described in Section 3.0 so that samples can be collected without leaks. The initial sampling will occur within 45 days of the SCAQMD's approval in writing of this VSP and then semi-annually thereafter.

2.1 LFG, LEACHATE, AND CONDENSATE VAPOR FLOW RATE MEASUREMENTS

Unless permanent flow meters have been installed at the sampling locations, flow at each sample collection point will be measured through the use of a TSI articulated probe thermal anemometer (Appendix B). The anemometer will be used to measure the air velocity in units of feet per second. All conveyance systems will be using round ducting so the following equations will be used to calculate the flow rate at each test location based on the measured air velocity. Measured air velocity will be calculated as the average of five (5) duct traverse points.

r = Radius in inches

A = Area in ft^2

$A = (3.14*r^2)/144$

V = Measured Velocity in ft/sec

$F = ft^3/sec = V * A$

All data will be collected on a field form and will be specific to the sample collection point.

2.2 VAPOR TEMPERATURE MEASUREMENTS

Vapor temperature measurements will also be made at every sample collection point. The same TSI articulated probe thermal anemometer will be used to collect vapor temperature measurements. All data will be collected on a field form and will be specific to the sample collection point.

2.3 SPECIATED ORGANICS SAMPLE COLLECTION

Vapor collection sample points are expected to be under approximately 5 inches of water (inH_2O) vacuum. Samples will be collected into 5-Liter SUMMA canisters with stainless steel piping connected to the sampling port. There will not be the need for flow restrictors or controllers. The following steps will be taken in the collection of the sample:

1) Remove the cap from the top of the sample valve;
2) While main sample valve is closed, connect vacuum pressure gauge to the canister inlet. Open valve and record initial canister vacuum. Close valve. Remove pressure gauge;
3) Connect stainless sample tubing from sample port to the canister inlet;
4) Open sample valve and allow canister to fill to line pressure (Approximately 1-minute);
5) Close sample valve, remove stainless pipe connection, cap sampling port, and recap SUMMA canister; and
6) Record the following sampling parameters on the filed form: date and time of sample collection, sample Location, and canister #.

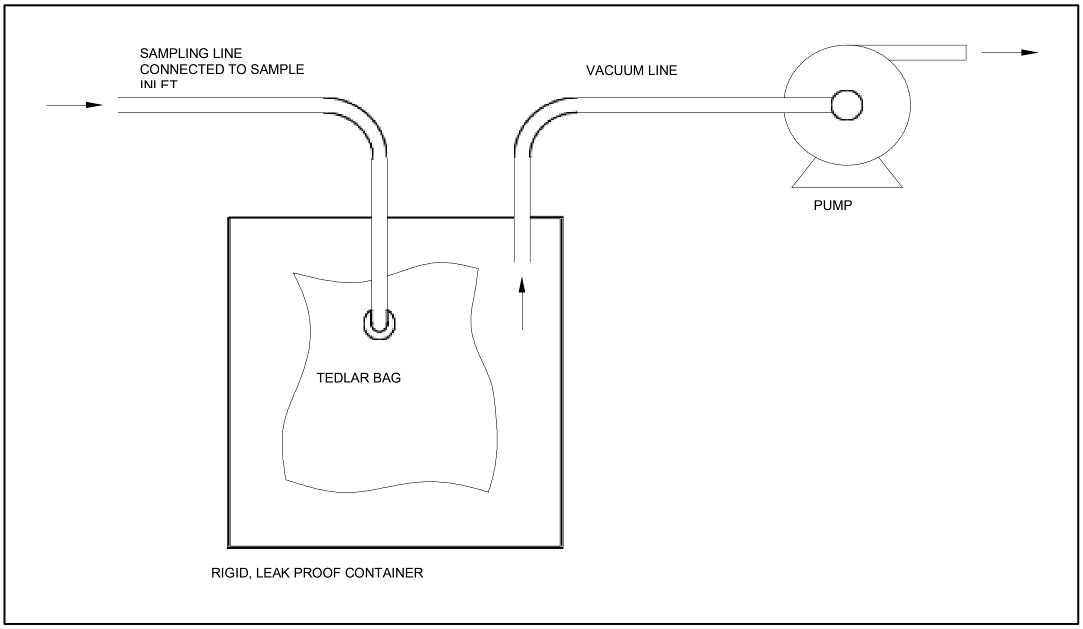
2.4 TOTAL REDUCED SULFUR COMPOUND AND SPECIATED SULFUR SAMPLE COLLECTION

Sulfur samples will be collected from the same sampling ports identified during the field survey outline in Section 3.0. Samples are collected using an air displacement sampling system, also known as a “lung sampler.” This method was used to eliminate any influence that an air pump would have on the sample collected. Figure 1 is a schematic diagram of how the air displacement sampler functions. The sample bag is placed into the sealed lung sampler and connected through a feed-through fitting to the sampling manifold. A second fitting is located in the wall of the lung sampler and connected to a vacuum pump. The container is then closed and sealed. As the pump withdraws air from the sealed container, an equal volume of sample air is drawn into the sample bag without making contact with the pump. This is complicated by the sample collection point being under slight vacuum as the bag will not begin to fill until the vacuum in the lung sampler is more than in the pipe. We currently anticipate using a sample pump operating at 10 liters per minute (lpm) to collect the sample over a 1.5-minute sampling period. The sample period may need to be adjusted based upon pipe pressure.

2.5 GAS HEAT RATING

Gas heat rating will be determined by analyzing each sample collected above for speciated organics also for methane content using American Society for Testing and Materials (ASTM) Method D-1946. The gas heating rating will be calculated by multiplying the methane content in percent by the heating value of methane of 1012 BTU/scf.

Figure 1: Air Displacement Sampler Diagram



3.0 SAMPLING LOCATIONS

Condition 72 calls for the sampling of leachate and condensate vapors from the following locations:

- The tank vents or manifolds which are representative of a set of tanks;
- The header/manifold from each leachate tank farm or manifold including Tank Farm #7, Tank Farm #9, North Perimeter Manifold, New East Perimeter Manifold, LC Manifold, landfill gas condensate storage tanks, and any other future tank farms or manifolds, with testing performed upstream of the piping connection to the LFG Collection and Conveyance System where LFG may affect results;
- The inlet of the flare(s) or thermal oxidizers (TOX) units prior to combustion; and
- The landfill gas header line(s) to the flares/TOX units (upstream of leachate/condensate vapor mixing).

Appendix A provides the current "As-built" drawings for the leachate and condensate vapor collection system. Prior to conducting the next sampling event, SCS will perform a field survey to identify the best locations for sample collection that meet the requirements of the condition. In addition, SCS will install sampling ports at every sample collection point, which is identified. The source test reports will include GPS coordinates of every sample location.

4.0 ANALYTICAL METHODS

Following sampling, the samples will be delivered to a third-party lab for analysis.

Analytical methods will include U.S. Environmental Protection Agency (EPA) Method TO-15 and sulfur via SCAQMD Method 307.91. The 1150.1 organic analytes listed in Table 1 below will be covered within the TO-15 analysis along with additional chemicals on the standard TO-15 list. H2S will be covered by Method 307-91. Methane will be covered by ASTM Method D-1946.

Table 1: SCAQMD Rule 1150.1 Toxic Air Contaminant List

SCAQMD Rule 1150.1 Table 1 Constituents			
Benzene	1,1-Dichloroethane	Tetrachloroethene	Trichloromethane
Benzyl chloride	1,2-Dichloroethane	Tetrachloromethane	Vinyl chloride
Chlorobenzene	1,1-Dichlroethene	Toluene	Xylenes
1,2-Dibromoethane	Dichloromethane	1,1,1-Trichloroethane	
Dichlorobenzene	Hydrogen Sulfide	Trichloroethene	

5.0 DATA REPORTING

Within 30 days of completion of the testing, a data report will be provided to SCAQMD, which will contain the following elements:

I. Introduction – Background information pertinent to the test will be presented in this section:

A. Condition 72 Requirements.
B. Test date(s).
C. Brief description of leachate vapor points being sampled.
D. Company name, contact person, mailing address, telephone number.
E. Facility name and physical location.
F. Name of testing organization, contact person, mailing address, telephone number.
G. Photographs of the locations where the sampling was performed.

II. Summary – This section will summarize in tabular form the test results for each sampling point: For each sampling location, the sampling report will provide velocities (pipe velocity in feet/second), flows (pipe flow in actual cubic feet/minute), measured concentrations, temperature and pressure as measured at the sampling probe, and sampling times.

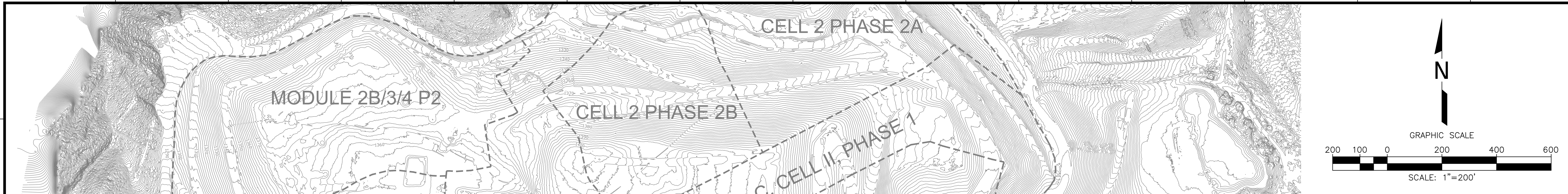
III. Test Procedures - This section will describe the test procedures utilized. This section will include: A brief description of the sampling and the procedures used to recover and analyze the samples. Include sampling durations, equipment specifications, sampling train information, and other pertinent details.

IV. Data and Calculations- This section will include copies of all raw data and at least one example calculation for every derived number showing all equations used:
A. All raw data used in the calculations:
B. Laboratory data, including blanks, quality assurance (QA) data, and results of analysis.
C. An example calculation for every calculated result showing how the result was derived from the raw data.
D. **Chain of custody documents.** Show names of custodians, method of transportation, departure and arrival times/locations.

In addition, this VSP incorporates that conditional approval of the original protocol by the SCAQMD, dated August 27, 2024 (**Appendix C**).

Appendix A

Chiquita Canyon Leachate Tank Farm: As built Drawings



LEGEND

- EXISTING CELL LIMITS (APPROXIMATE)
- EXISTING FRAK TANK (COLOR BASED ON TANK TYPE)

GENERAL DRAWING NOTES:

1. EXISTING TOPOGRAPHIC SURVEY INFORMATION SHOWN WAS PROVIDED BY PROPELLOR. AERIAL PHOTOGRAPHY DATED JUNE 2, 2026.
2. NORTH ARROW SHOWN HERE IS REFERENCE TO THE CALIFORNIA STATE PLANE ZONE V COORDINATE SYSTEM, NAD 83.

NO.	REVISION	DATE

SHEET TITLE: TANK FARM LOCATION MAP

PROJECT TITLE: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

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PROJ. NO. 01204123.45 | DWN. BY: RR | ACAD FILE: F:/ENGINEERS
DSN. BY: - | CHK. BY: - | APP. BY: -

DATE: 06/10/2026

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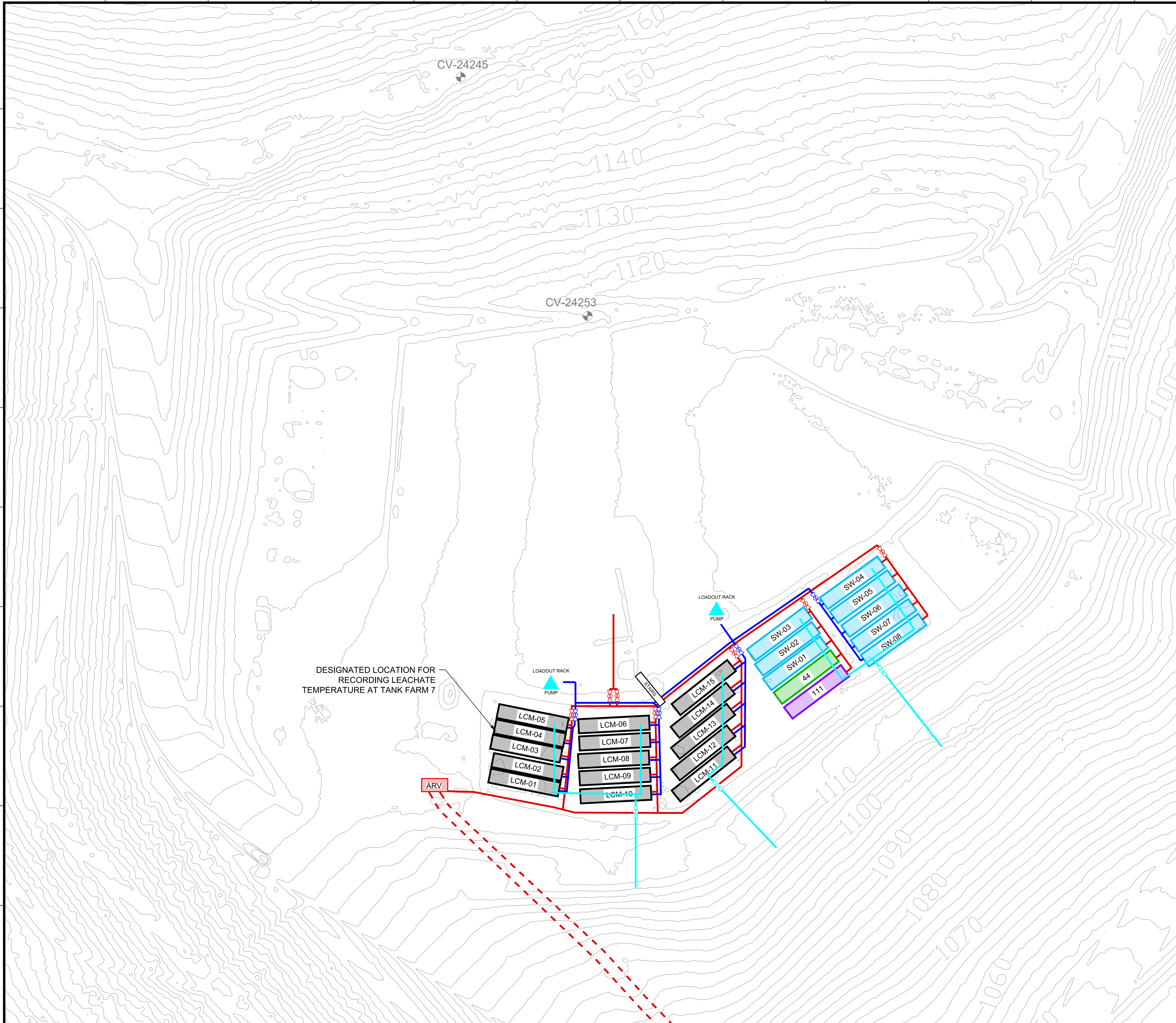
SHEET: 1



N

GRAPHIC SCALE

30 15 0 30 60 90

SCALE: 1"= 30'

LEGEND

1150	TOPOGRAPHIC CONTOUR
	EXISTING FRAC TANK - CONDENSATE
	EXISTING FRAC TANK - B SUMP
	EXISTING FRAC TANK - STORM WATER
	EXISTING FRAC TANK - LCM
4"	EXISTING VACUUM PIPE
4"	EXISTING INLET FORCEMAIN PIPE
3" / 6"	EXISTING FORCEMAIN LINE
4"	EXISTING LOADOUT PULL PIPE
	EXISTING PUMP / TRUCK LOADOUT

GENERAL DRAWING NOTES:

1. EXISTING TOPOGRAPHIC SURVEY INFORMATION SHOWN WAS PROVIDED BY PROPELLOR. AERIAL PHOTOGRAPHY DATED JUNE 2, 2026.
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NO.	REVISION	DATE

SHEET TITLE: TANK FARM 7

PROJECT TITLE: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

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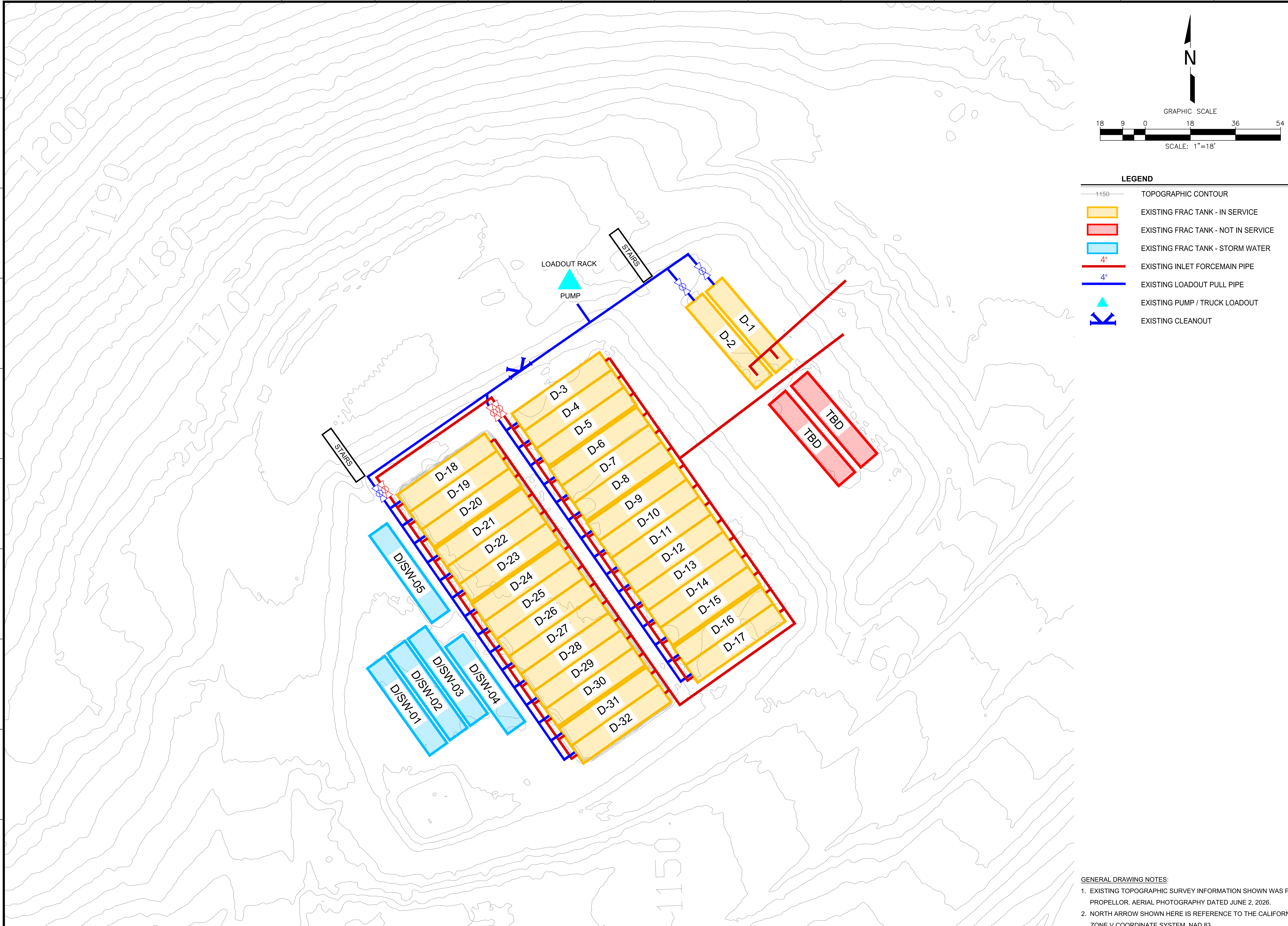
DSN. BY: -	CHK. BY: -	APP. BY: -

DATE: 06/10/2026

SCALE: AS SHOWN

SHEET: 2



LEGEND

- 1150 — TOPOGRAPHIC CONTOUR
- EXISTING FRAC TANK - IN SERVICE
- EXISTING FRAC TANK - NOT IN SERVICE
- EXISTING FRAC TANK - STORM WATER
- 4" — EXISTING INLET FORCEMAIN PIPE
- 4" — EXISTING LOADOUT PULL PIPE
- EXISTING PUMP / TRUCK LOADOUT
- EXISTING CLEANOUT

GENERAL DRAWING NOTES:

1. EXISTING TOPOGRAPHIC SURVEY INFORMATION SHOWN WAS PROVIDED BY PROPELLOR. AERIAL PHOTOGRAPHY DATED JUNE 2, 2026.
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NO.	REVISION	DATE

SHEET TITLE: TANK FARM 10

PROJECT TITLE: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

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PROJ. NO. 01204123.41 | DWN. BY: SRM / CNW | ACAD FILE: F:/ENGINEERS
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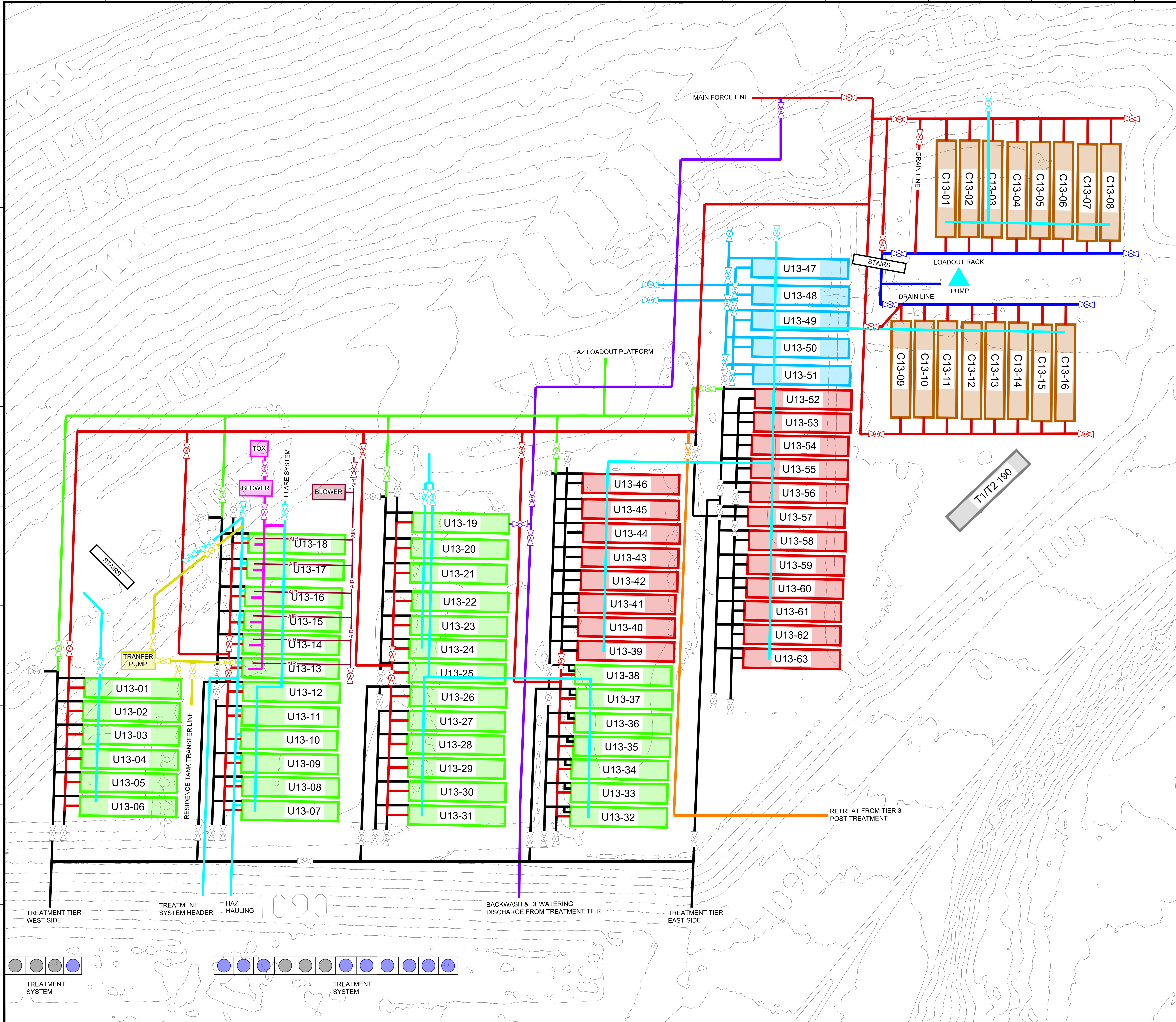
DATE: 06/10/2026

SCALE: AS SHOWN

SHEET: 3



N

GRAPHIC SCALE

22 11 0 22 44 66

SCALE: 1" = 22'

LEGEND

1150	TOPOGRAPHIC CONTOUR
4"	EXISTING HAZ LOADOUT PIPE
4"	EXISTING TREATMENT PIPE
4"	EXISTING RETREAT PIPE
8"	EXISTING INLET FORCEMAIN PIPE
4"	EXISTING BACKWASH & DEWATERING PIPE
4"	EXISTING SLUDGE TANKS FILL/PULL PIPE
4"	EXISTING VACUUM PIPE
3"/ 6" AIR	EXISTING BLOWER PIPE
4"	EXISTING RECIRC PIPE
4"	EXISTING DRAIN PIPE
4"	EXISTING LOADOUT PULL PIPE
	EXISTING POLYVALVE (COLOR BASED ON PIPE TYPE)
	EXISTING PUMP / TRUCK LOADOUT
	EXISTING FRAC TANK - CLARIFIER
	EXISTING FRAC TANK - INFLUENT
	EXISTING FRAC TANK - RESERVE INFLUENT
	EXISTING FRAC TANK - SLUDGE
	EXISTING FRAC TANK - H2S CONDENSATE

GENERAL DRAWING NOTES:

1. EXISTING TOPOGRAPHIC SURVEY INFORMATION SHOWN WAS PROVIDED BY PROPELLOR. AERIAL PHOTOGRAPHY DATED JUNE 2, 2026.
2. NORTH ARROW SHOWN HERE IS REFERENCE TO THE CALIFORNIA STATE PLANE ZONE V COORDINATE SYSTEM, NAD 83.

NO.	REVISION	DATE

SHEET TITLE: TANK FARM 13 PRE-TREATMENT

PROJECT TITLE: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

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DATE: 06/09/2026

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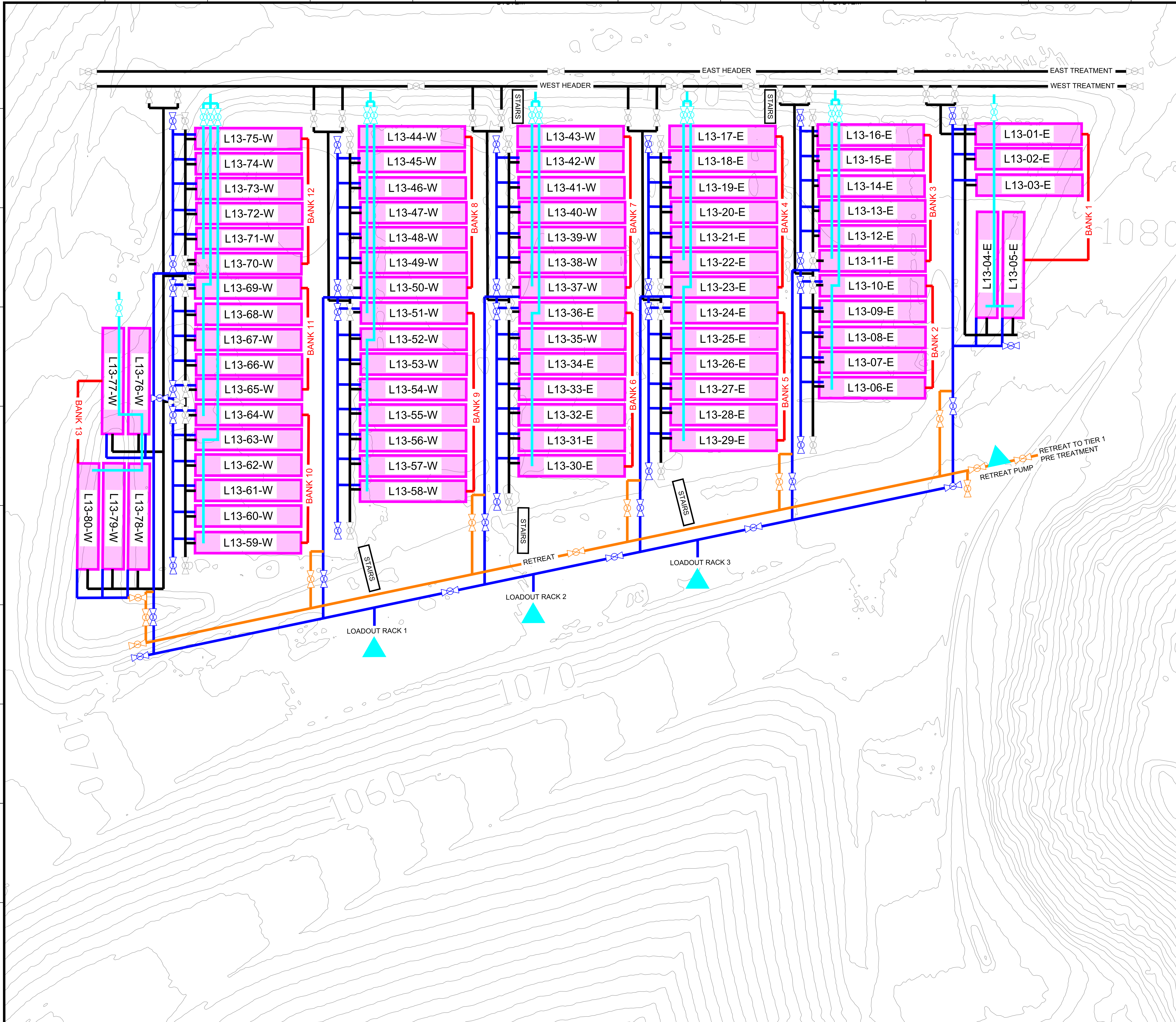

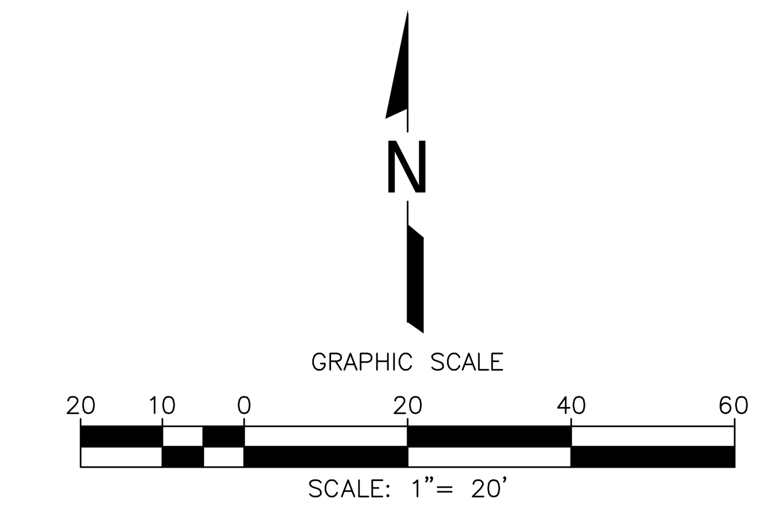

LEGEND

1150	TOPOGRAPHIC CONTOUR
4"	EXISTING TREATMENT FILL PIPE
4"	EXISTING LOADOUT PULL PIPE
4"	EXISTING RETREAT PIPE
4"	EXISTING SYSTEM VACUUM PIPE
	EXISTING POLYVALVE (COLOR BASED ON PIPE TYPE)
	EXISTING PUMP / TRUCK LOADOUT
	EXISTING FRAC TANK - POST TREATMENT

EAST TREATMENT
BANK#1
BANK#2
BANK#3
BANK#4
BANK#5
BANK#6

WEST TREATMENT
BANK#7
BANK#8
BANK#9
BANK#10
BANK#11
BANK#12
BANK#13

GENERAL DRAWING NOTES:

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NO.	REVISION	DATE

SHEET TITLE: TANK FARM 13 POST TREATMENT

PROJECT TITLE: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

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DATE: 06/10/2026

SCALE: AS SHOWN

SHEET: 5

APPENDIX B

Information on TSI Articulated Probe Thermal Anemometer

TSI THERMAL ANEMOMETRY PROBES

FOR MAXIMUM FLEXIBILITY IN DESIGNING YOUR THERMAL ANEMOMETRY APPLICATION

UNDERSTANDING, ACCELERATED

TABLE OF CONTENTS

INTRODUCTION TO THERMAL ANEMOMETRY

Thermal anemometers measure fluid velocity by sensing the changes in heat transfer from a small, electrically-heated element exposed to the fluid. In the "constant temperature anemometer," the cooling effect caused by the flow passing the element is balanced by the electrical current to the element, so the element is held at a constant temperature. The change in current due to a change in flow velocity shows up as a voltage at the anemometer output.

A key feature of the thermal anemometer is its ability to measure very rapid changes in velocity. This is accomplished by coupling a very fine sensing element (typically a wire four to six microns in diameter or a platinum thin film deposited on a quartz substrate) with a fast feedback circuit which compensates for the drop in the natural sensor response. Time response to flow fluctuations as short as a few microseconds can be achieved. For this reason, the thermal anemometer has become a standard tool for researchers studying turbulence. The small sensor size, normally only a millimeter in length, also makes the technique valuable in applications where access is difficult or larger sensors obstruct the flow.

Since the actual measurement is of heat transfer between the sensor and its environment, the thermal anemometer will respond to changes in parameters other than velocity, such as temperature, pressure, and fluid composition. While this adds to versatility, it also means that when more than one parameter is changing, special techniques must be used to extract velocity. Modern systems will automatically correct the velocity reading for temperature changes.

When selecting a thermal anemometry probe, the user must choose between film and wire sensors. The choice is based on the fluid characteristics, the velocity range, the number of velocity components, contamination in the flow, and access to the flow.

The traditional sensor for research thermal anemometry has been a fine wire. For very low turbulence intensities, the wire sensor is still superior–and the smaller the wire, the better the results. For those applications that require a wire sensor, the 4 micrometer-diameter platinum-coated tungsten wire is almost a standard for measurements at normal room temperatures and below. Tungsten is very strong and has a high temperature coefficient of resistance. It will, however, deteriorate at high temperatures in oxidizing atmospheres (such as air). Platinum wires, though weaker, can also be made very small and will withstand high temperature in an oxidizing atmosphere. If more strength is needed at high temperatures, an alloy such as platinum-iridium should be selected.

The rigidity and strength of cylindrical film sensors, relative to wire sensors, make them the preferred choice in a wide range of thermal anemometry applications. Rigidity is especially important for multi-sensor measurements where the algorithms used for data reduction assume a straight sensor. Also, film sensors are less susceptible to damage or coating by particles in the flow than are wire sensors.

SENSOR PROBE SELECTION

The chart below lists all the probes featured in this catalog and summarizes their key selection characteristics:

Cylindrical Sensors

Model No.*	Page Number	Designation	Size	Temperature	Fluid	Sensor Type	Sensor Orientation	Sensor Position
1201	6	S	R	L	G	F	90	I
1210	6	S	R	L	G,L	W,F	90	I
1220	6	S	R	H	G	W,F	90	I
1260A	6	S	M	L	G,L	W,F	90	I
1276	7	S	SM	L	G,L	W,F	90	I
1214	7	S	R	L	G	W,F	90	I
1213	7	S	R	L	G,L	W,F	45	I
1211	7	S	R	L	G	W,F	0	I
1212	8	S	R	L	G,L	W,F	90	U
1222	8	S	R	H	G	W,F	90	U
1262A	8	S	M	L	G,L	W,F	90	U
1277	8	S	SM	L	G	F	0	U
1218	9	BL,S	R	L	G,L	W,F	90	U
1261A	9	BL,S	M	L	G,L	W,F	90	U
1241	10	X	R	L	G,L	W,F	45	I
1248A	10	X	M	L	G,L	W,F	45	I
1240	10	X	R	L	G,L	W,F	90	I
1247A	11	X	M	L	G,L	W,F	90	I
1246	11	X	R	L	G,L	W,F	45	U
1245	11	X	R	L	G,L	W,F	90	U
1249A	12	X	M	L	G,L	W,F	45	U
1243	12	BL,X	R	L	G,L	W,F	45	U
1244	12	II	R	L	G,L	W,F	90	I
1299	13	T	OP	L	G	F	54	I
1299A	13	T	OP	L	G	F	-	U

*Probes are listed in numerical order in the index on page 26.

Sensor Designation

Cylindrical Sensors

- S = Single
- T = Triple sensor
- II = 2 parallel sensors
- BL = Boundary layer
- X = "X" probe

Sensor Size

(Diameter of probe body closest to sensor)

- R = Regular (3.2 mm)
- M = Miniature (1.5 mm)
- SM = Subminiature (0.9 mm)
- OP = One Piece (4.6 mm)

Temperature

(Maximum exposure temperature of probe body)**

- L = 150°C, (except 60°C for 1201)
- H = 300°C

Maximum temperature for water probes is approximately 30°C

Fluid

- G = Gas
- L = Liquid

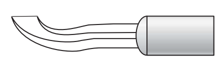
Sensor Type

- W = Wire
- F = Platinum film

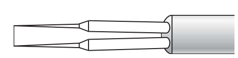
Sensor Orientation

(Relative to connector end of probe)

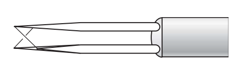
0 = 0°



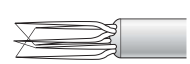
90 = 90°



45 = 45°



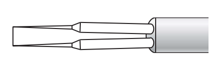
54 = 54.74°



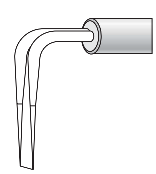
Sensor Position

(Relative to connector end of probe)

I = In-line



U = Upstream



PROBE SELECTION

The probe family includes hot film sensors and hot wire sensors. The choice between them is critical for most applications. Hot films consist of a thin film of platinum deposited on a quartz substrate, typically a cylinder attached to the sensor supports. Various cylinder diameters permit different spatial resolutions.

This catalog describes a full line of standard probes mainly classified by sensor type, the number of sensors, and the direction the mean flow moves relative to the probe body. They should handle the vast majority of applications. The catalog also includes probe supports (usually required since they contain the necessary cable connections) and probe shields which help protect the delicate sensor.

FOUR STEPS IN CHOOSING A PROBE

The four steps outlined here help determine the key measurement and environmental parameters that must be known in order to select the best probe and probe support for an application. The selection process then becomes relatively straightforward.

Step 1. Identify environmental conditions (determines the applicable sensors)

High temperature gases–Sensors are normally operated well above the environment temperature. The maximum operating temperature of film sensors is 425°C, while for tungsten wires it is 300°C. Platinum wires can operate at much higher temperatures but are much weaker than tungsten. Platinum iridium is stronger than platinum but has a lower temperature coefficient (providing lower S/N ratio). The probe must also be selected for the appropriate temperature range.

Clean liquids–Most liquids are sufficiently conductive that the sensor element must be insulated. Thus, only coated film sensors ("W" designation) can be used. Standard construction techniques for probes used in conductive liquids limits the fluid temperature to approximately 30°C. In a truly insulating liquid (e.g. oil), a non-coated sensor should be used since it tends to collect less contamination. In liquids, boundary layer lag can substantially reduce the expected frequency response.

Step 2. Number of velocity components to be measured (there are limits to the magnitude of the turbulence intensity that can be accurately measured)

A single cylindrical sensor perpendicular to the flow will give a good measurement of the instantaneous velocity in the mean flow direction.

Two cylindrical sensors, properly oriented, will measure two components of velocity.

Three cylindrical sensors, properly oriented, will measure all three velocity components.

Step 3. Hot wires versus cylindrical film sensors where either can be used

Hot wires–Provide the best S/N ratio and generally better frequency response than film sensors. With multiple sensors, they do not stay positioned as well (lengthen and bend when heated), causing errors in velocity component calculations.

Cylindrical film sensors–Generally do not contaminate as easily(due to larger diameter) and will not shift resistance due to strain in a high velocity environment or due to particle impact.

Step 4. Probe and support selection

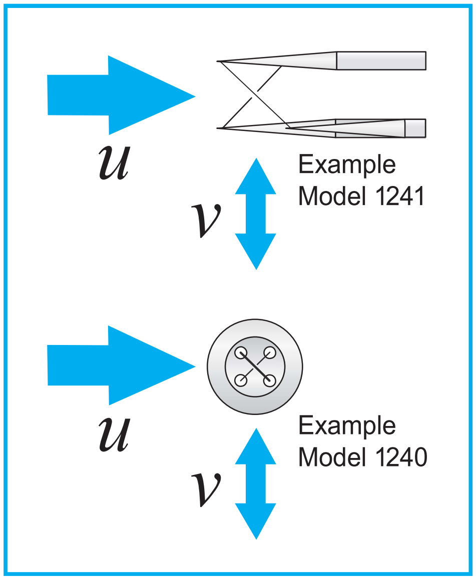
Once the type and number of sensors is determined, further selections depend on the access to the flow and where the measurement is made. Right angle adapters, miniature probes, andcross flow designs are all variations that help you get the sensor where it belongs with minimum flow field disturbance.

X-PROBE SELECTION

When selecting an X-probe, keep in mind that an X-probe measures two components of velocity (U and V) that are both in the plane formed by the two sensors. The U and V components will each be at 45 degrees to each sensor. It is assumed that the flow is two-dimensional, with the W component (normal to the plane formed by the two sensors) small in comparison to the total velocity vector. The X-probe should be aligned such that the major flow is in the U direction.

SPECIAL DESIGNS

If you find that no standard probe meets your requirements, define your measurement needs according to the steps outlined and contact TSI. This is often an iterative process as we work with you to get the best possible answer, but it is one that has proved worthwhile to thousands of users around the world, each having a unique application.



HOW TO USE THIS CATALOG

Once you have completed the above steps, you are ready to use the catalog to find the correct probe and probe support for your application. As closely as possible, the catalog has been designed to lead you logically to the probe you need.

The catalog is organized according to the following characteristics:

+ First, by broad sensor type
+ Second, by the number of sensors (one, two, or three) mounted on the probe
+ Third, by the direction of the mean flow relative to the probe body (end flow or cross flow)
+ Fourth, by the specific configuration of the probe (high temperature, miniature, etc.)

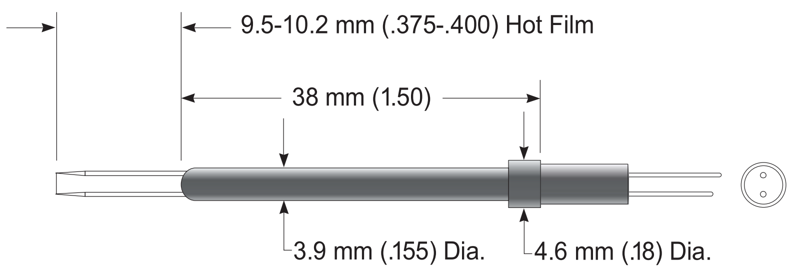
Once you have located the type of probe you need, review the list of recommended sensors to determine if the specific sensor type (air or water, wire or film) which you need is available. See the sensor specification table on page 5 for a description of the sensor designations listed in the probe section and detailed specifications on each type of sensor.

When the probe type has been determined, the final step is to locate the best probe support and shield. A wide variety of supports and shields are listed in the pages following the probes. Your choice will be largely based on access requirements.

PROBES FOR SINGLE CYLINDRICAL SENSORS

Probes for single cylindrical sensors are used for one-dimensional flow measurements. Within this category, the Model 1210 and its equivalent disposable probe, the Model 1201, are the most frequently used probe models.

Model 1201 Disposable Probe

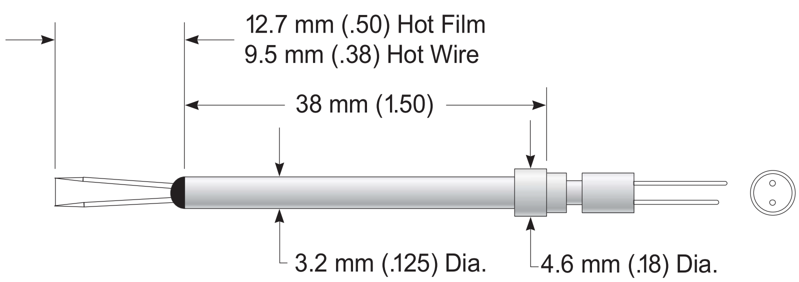


Recommended Sensors

For Gas Applications

+ 1201-6 (package of 6)
+ 1201-12 (package of 12)
+ The 1201 probes have a -20 film sensor.
+ Max. Fluid Temp. = 60°C

Model 1210 General Purpose Probe



Recommended Sensors

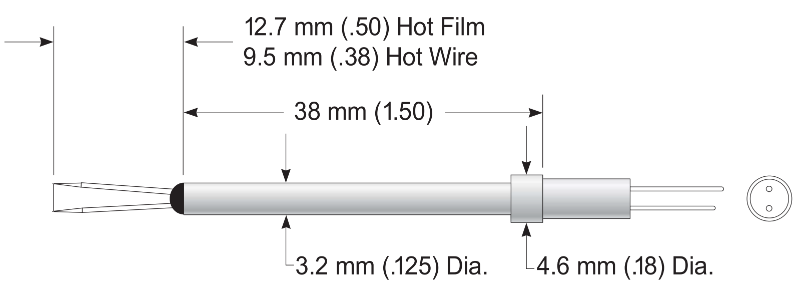
For Gas Applications

+ 1210-T1.5
+ 1210-20
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1210-20W

Model 1220 High Temperature Straight Probe

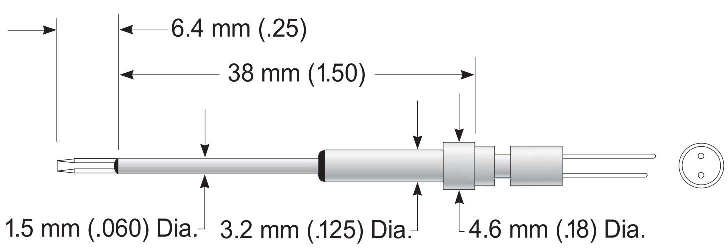


Recommended Sensors

For Gas Applications

+ 1220-PI2.5
+ 1220-20
+ Max. Fluid Temp. = 300°C

Model 1260A Miniature Straight Probe



Recommended Sensors

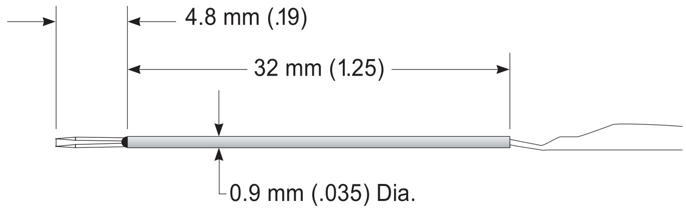
For Gas Applications

+ 1260A-T1.5
+ 1260A-10
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1260A-10W

Model 1276 Subminiature Straight Probe



Recommended Sensors

For Gas Applications

+ 1276-P.5*
+ 1276-10A
+ Max. Fluid Temp. = 150°C

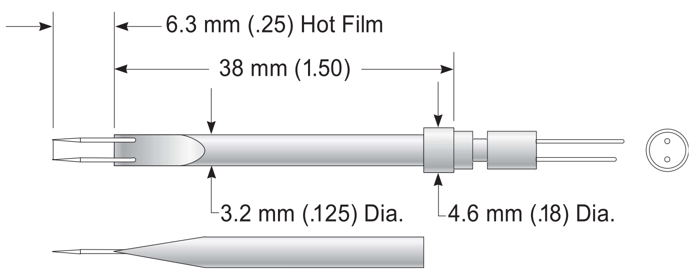
For Liquid Applications

+ 1276-10AW

* Use for temperature measurement only with constant current bridge.

Model 1214 Streamlined Probe

For high speed (e.g. supersonic) flows



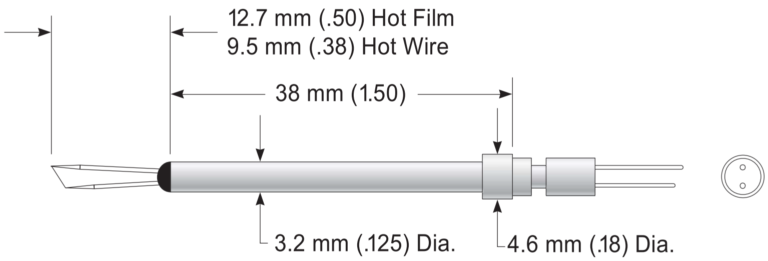
Recommended Sensors

For Gas Applications

+ 1214-T1.5
+ 1214-20
+ Max. Fluid Temp. = 150°C

Model 1213 Sensor 45° to Probe

Single sensors 45° to probe axis can be used in steady flows to measure turbulent shear stress or two components of velocity by rotating the probe about its axis.



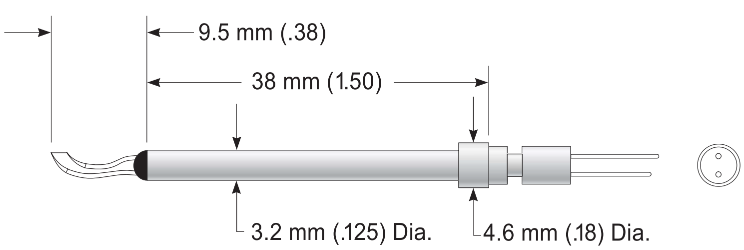
Recommended Sensors

For Gas Applications

+ 1213-T1.5
+ 1213-20
+ Max. Fluid Temp.= 150°C

Model 1211 Standard Probe

In cross flow applications, probe interference is reduced by mounting the sensor parallel to the probe body.



Recommended Sensors

For Gas Applications

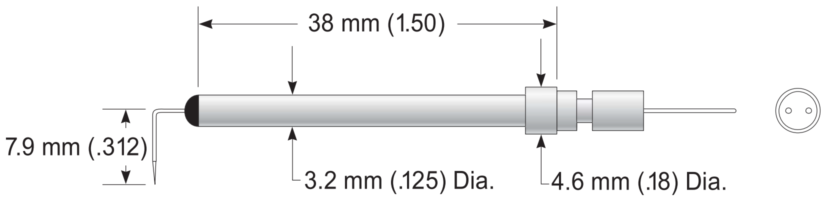
+ 1211-T1.5
+ 1211-10
+ 1211-20
+ Max. Fluid Temp.= 150°C

Dimensions in parentheses are in inches.

PROBES FOR SINGLE CYLINDRICAL SENSORS

For minimum probe interference in cross flow applications, the sensor needles are bent so the sensor is upstream of the probe.

Model 1212 Standard Single Sensor Probe



Recommended Sensors

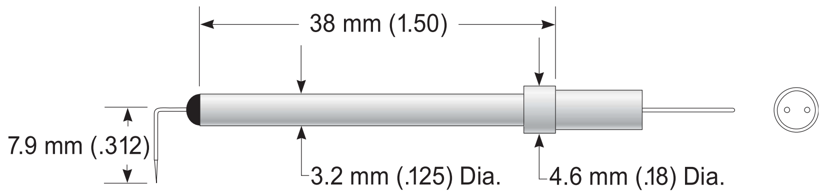
For Gas Applications

- 1212-T1.5
- 1212-20
- Max. Fluid Temp. = 150°C

For Liquid Applications

- 1212-20W

Model 1222 High Temperature Single Sensor Probe

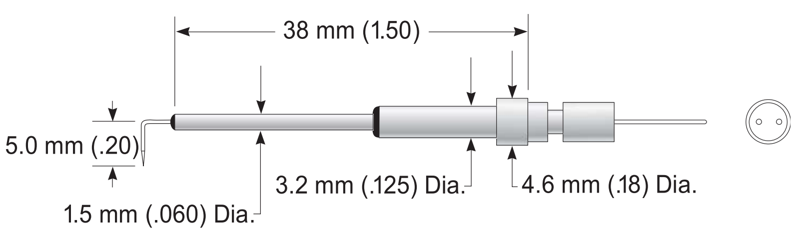


Recommended Sensors

For Gas Applications

- 1222-PI2.5
- 1222-20
- Max. Fluid Temp. = 300°C

Model 1262A Miniature Probe



Recommended Sensors

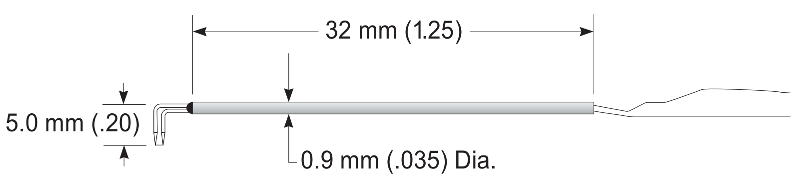
For Gas Applications

- 1262A-T1.5
- 1262A-10
- Max. Fluid Temp. = 150°C

For Liquid Applications

- 1262A-10W

Model 1277 Subminiature Probe



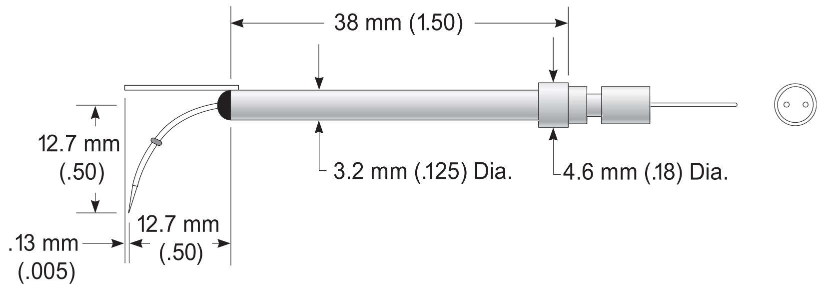
Recommended Sensors

For Gas Applications

- 1277-10A
- Max. Fluid Temp. = 150°C

Boundary layer probes provide a protective pin to allow measurements very near the surface and a long radius bend to minimize disturbances.

Model 1218 Standard Boundary Layer Probe



Recommended Sensors

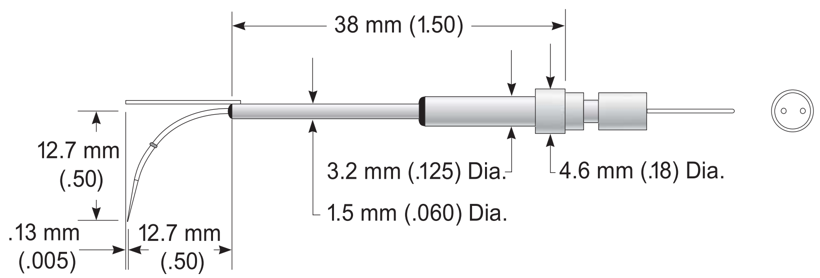
For Gas Applications

+ 1218-T1.5
+ 1218-10
+ 1218-20
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1218-20W

Model 1261A Miniature Boundary Layer Probe



Recommended Sensors

For Gas Applications

+ 1261A-T1.5
+ 1261A-10
+ Max. Fluid Temp. = 150°C

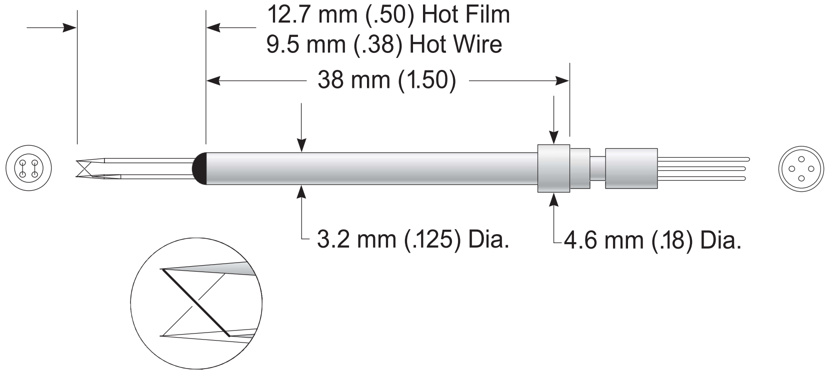
For Liquid Applications

+ 1261A-10W

PROBES FOR DUAL CYLINDRICAL SENSORS

Dual sensor probes position two sensors in close proximity, generally in an "X" configuration, for measuring two components of flow and the correlation between them. For accurate measurements, the maximum turbulence intensity is limited by the sensitivity to the flow perpendicular to the measured components.

Model 1241 End Flow "X" Probe



Recommended Sensors

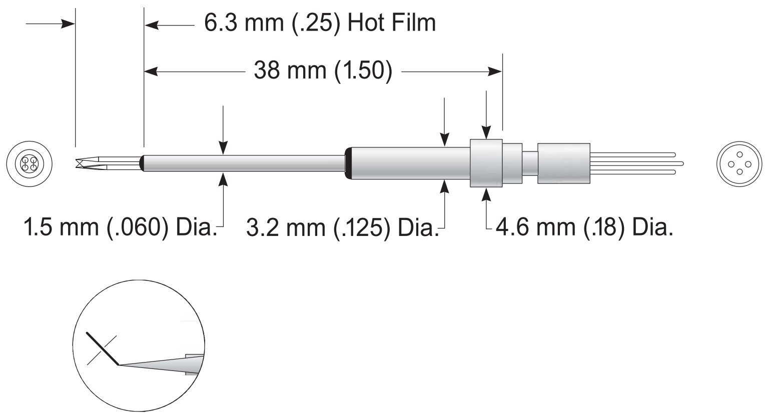
For Gas Applications

+ 1241-T1.5
+ 1241-20
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1241-20W

Model 1248A Miniature End Flow "X" Probe



Recommended Sensors

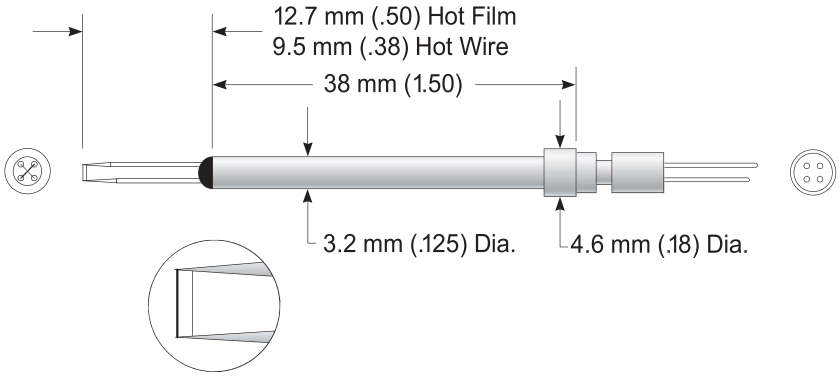
For Gas Applications

+ 1248A-T1.5
+ 1248A-10
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1248A-10W

Model 1240 Standard Cross Flow "X" Probe



Recommended Sensors

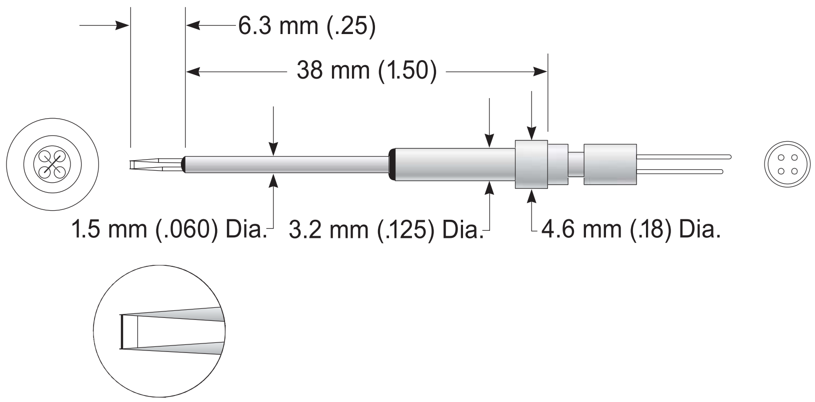
For Gas Applications

+ 1240-T1.5
+ 1240-20
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1240-20W

Model 1247A Miniature Cross Flow "X" Probe



Recommended Sensors

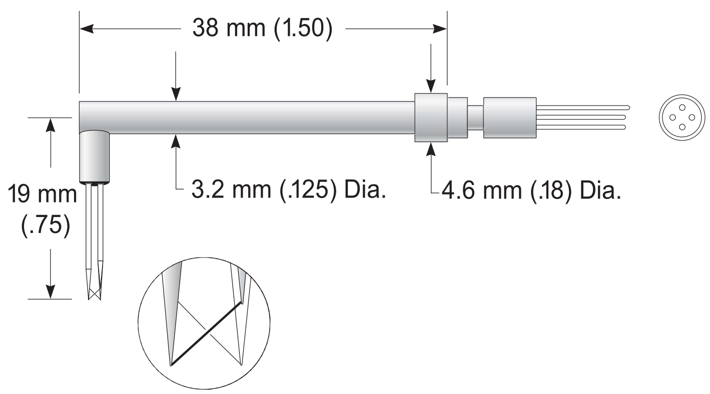
For Gas Applications

- 1247A-T1.5
- 1247A-10
- Max. Fluid Temp.= 150°C

For Liquid Applications

- 1247A-10W

Model 1246 Cross Flow "X" Probe, Sensors Upstream



Recommended Sensors

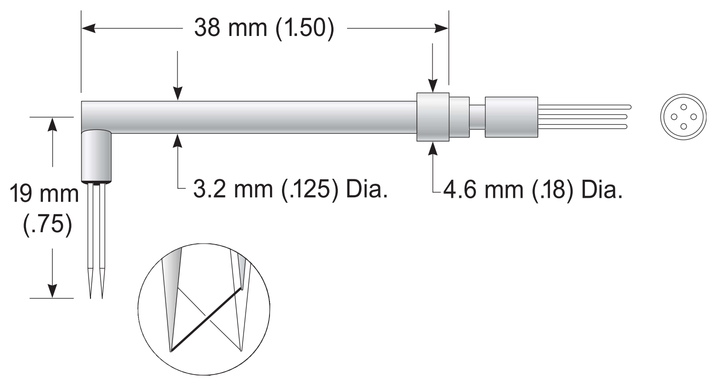
For Gas Applications

- 1246-T1.5
- 1246-20
- Max. Fluid Temp.= 150°C

For Liquid Applications

- 1246-20W

Model 1245 Cross Flow "X" Probe, Sensors Upstream



Recommended Sensors

For Gas Applications

- 1245-T1.5
- 1245-20
- Max. Fluid Temp.= 150°C

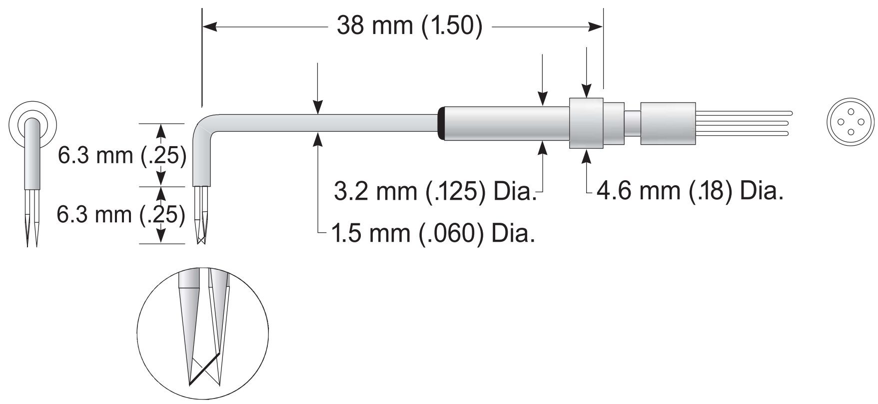
For Liquid Applications

- 1245-20W

Dimensions in parentheses are in inches.

PROBES FOR DUAL CYLINDRICAL SENSORS

Model 1150 Standard Probe Support



Recommended Sensors

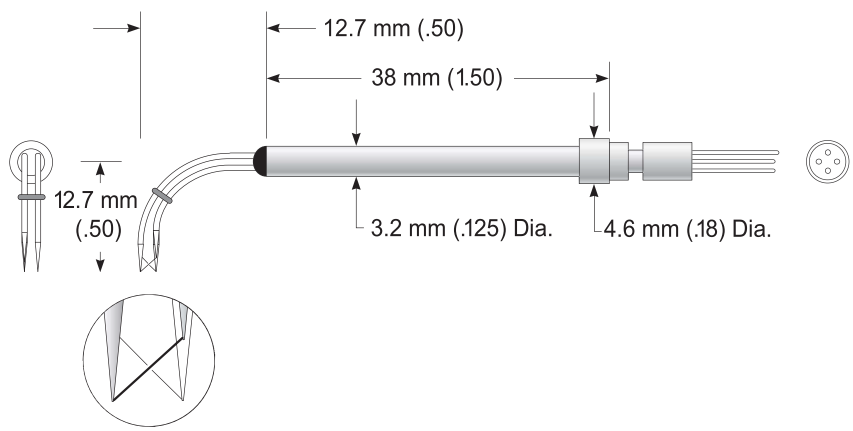
For Gas Applications

+ 1249A-T1.5
+ 1249A-10
+ Max. Fluid Temp. = 150°C

For Liquid Applications

+ 1249A-10W

Model 1160 High Temperature Probe Support



Recommended Sensors

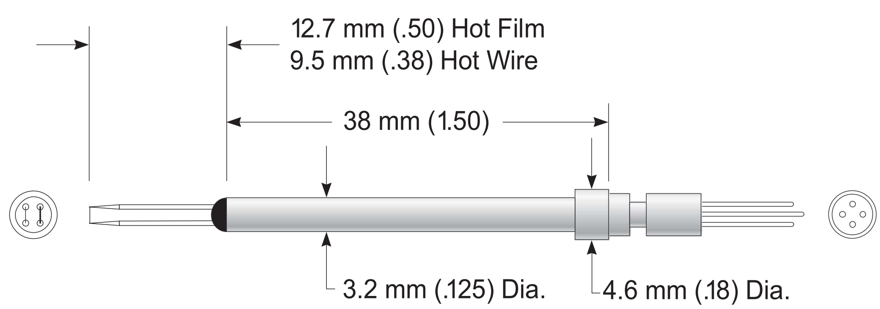
For Gas Applications

+ 1243-T1.5
+1243-20
+Max. Fluid Temp. = 150°C

For Liquid Applications

+1243-20W

Model 1244 End Flow Parallel Sensor Probe



Recommended Sensors

For Gas Applications

+ 1244-T1.5
+ 1244-20
+ Max. Fluid Temp. = 150°C

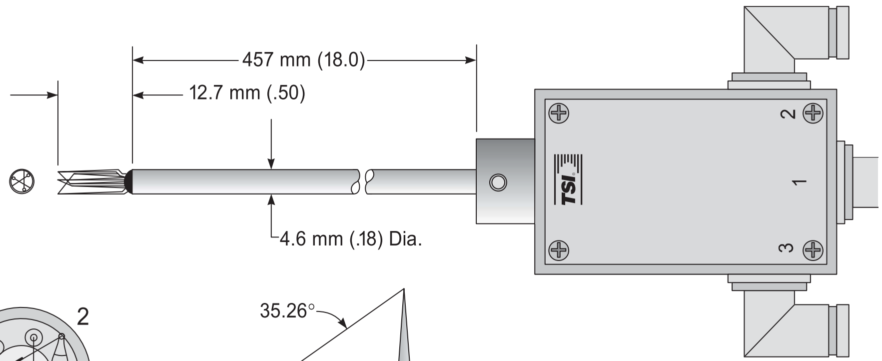
For Liquid Applications

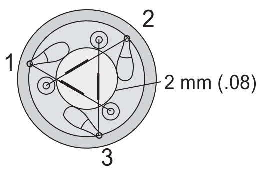
+ 1244-20W

PROBES FOR THREE CYLINDRICAL SENSORS

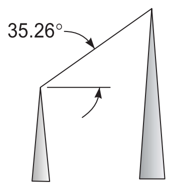
Three-sensor probes are used to locate three sensors in close proximity. They are generally used to measure all three velocity components. Good measurements require that the flow vector stays within the one octant defined by the three sensors. The sensors are located optimally for maximum spatial resolution and minimum probe interference.

Model 1299 End Flow 3-D Probe





Enlarged End View



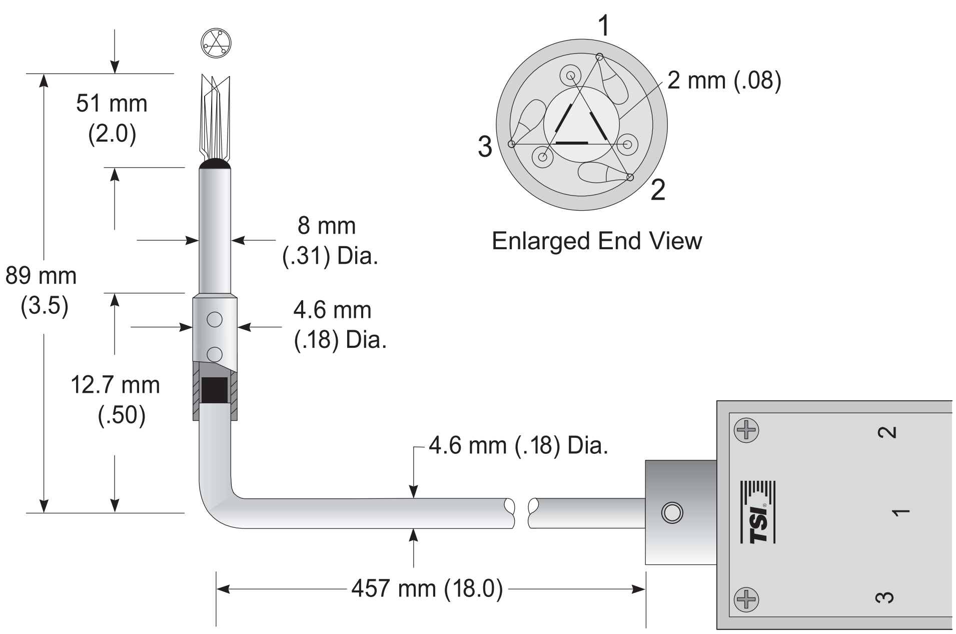
Sensor Angles

Recommended Sensors

For Gas Applications

+ 1299-18-20
+ Max. Fluid Temp.= 150°C

Model 1299A Cross Flow 3-D Probe



Enlarged End View

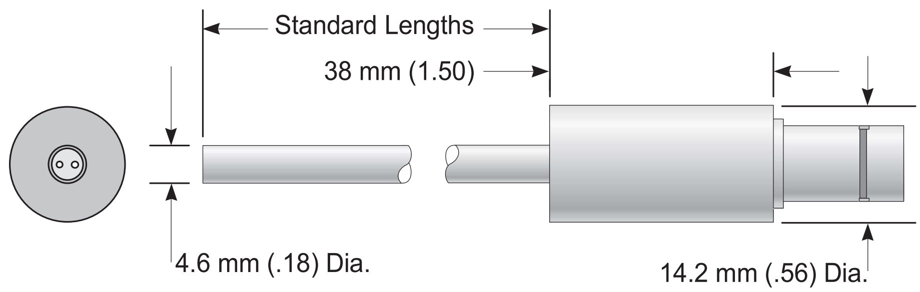
Recommended Sensors

For Gas Applications

+ 1299A-18-20
+ Max. Fluid Temp.= 150°C

SINGLE SENSOR PROBE SUPPORTS

Model 1150 Standard Probe Support

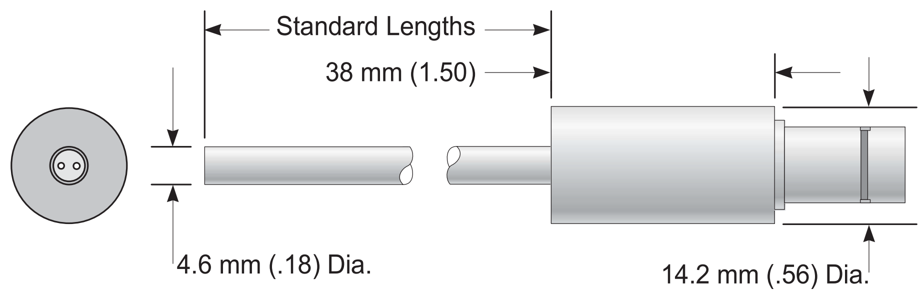


Designed for most standard TSI single sensor plug-in probes.

Specify

+ 1150-6 for 152 mm (6 in.) length
+ 1150-18 for 457 mm (18 in.) length
+ 1150-36 for 915 mm (36 in.) length
+ Max. Fluid Temp. = 150°C

Model 1160 High Temperature Probe Support

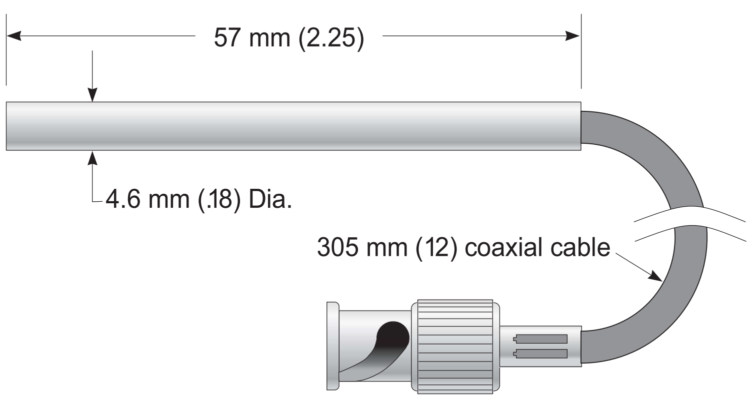


Designed for most standard TSI single sensor plug-in probes.

Specify

+ 1160-6 for 152 mm (6 in.) length
+ 1160-18 for 457 mm (18 in.) length
+ Max. Fluid Temp. = 300°C

Model 1151 Probe Support

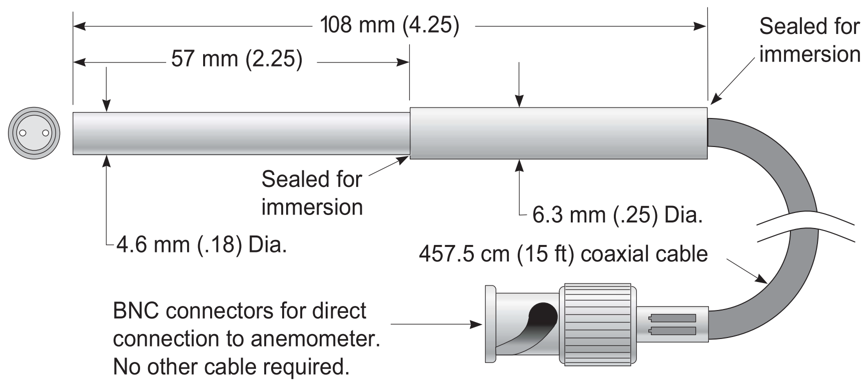


Convenient probe support for small spaces.

Specify

+ 1151-1
+ Max. Fluid Temp. = 150°C

Model 1159 Immersible Probe Support

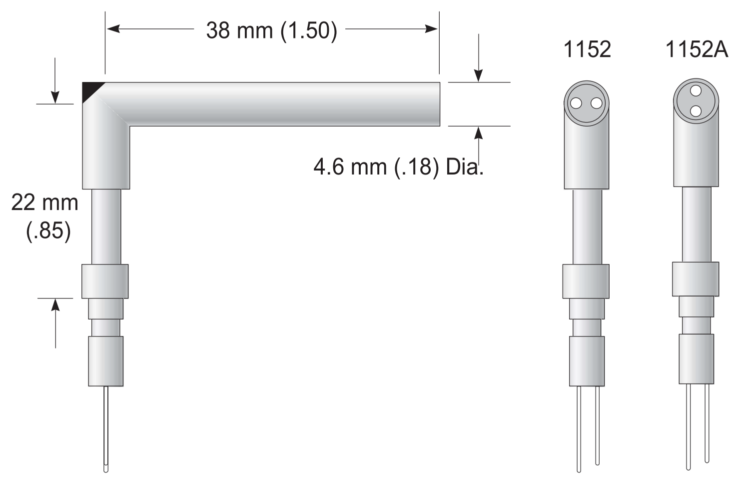


Small probe can be immersed entirely for liquid flow applications.

Specify

+ 1159-15

Model 1152 90° Angle Adapter



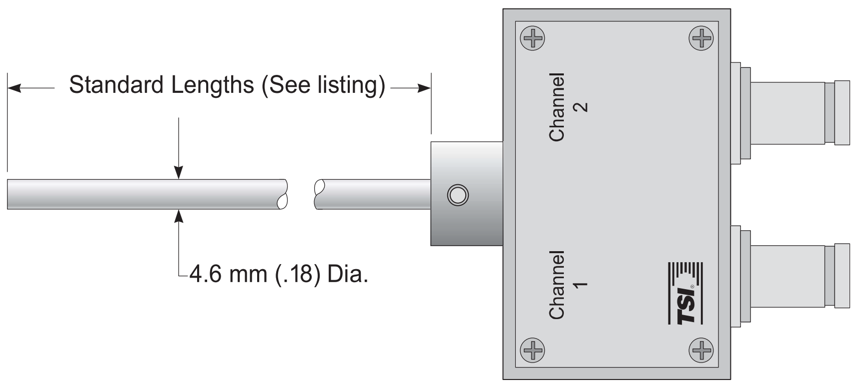
Right angle bend provides access to upstream points with straight probes.

Specify

+ 1152
+ 1152A

DUAL SENSOR PROBE SUPPORTS

Model 1155 Standard Probe Support

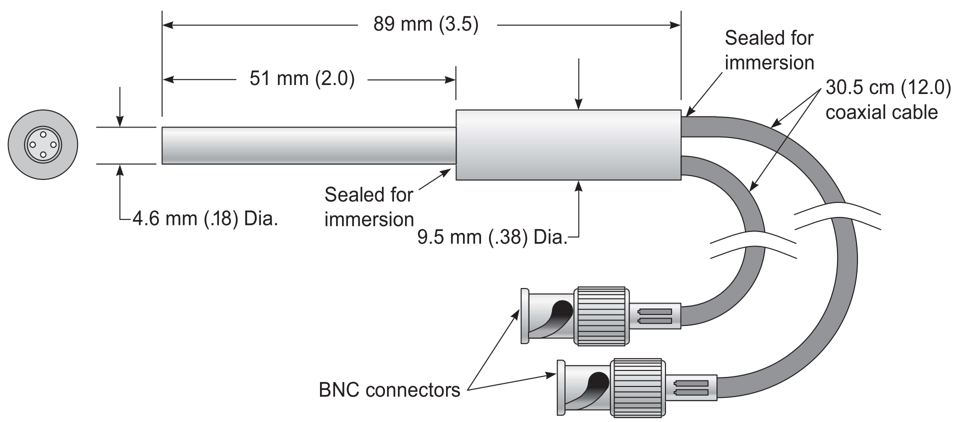


Designed for most standard TSI dual sensor plug-in probes.

Specify

+ 1155-6 for 152 mm (6 in.) length
+ 1155-18 for 457 mm (18 in.) length
+ 1155-36 for 915 mm (36 in.) length
+ Max. Fluid Temp. = 150°C

Model 1156-1 Probe Support

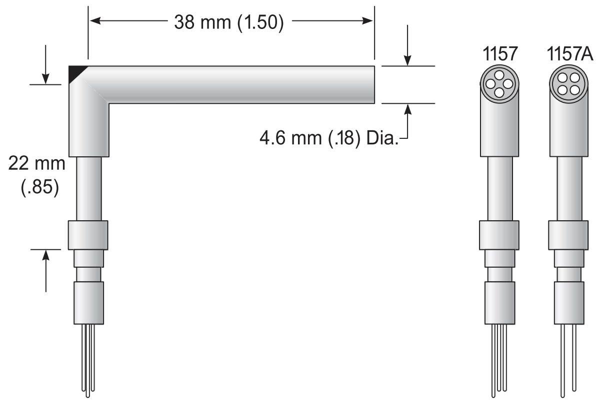


Convenient probe support for small spaces.

Specify

+ 1156-1
+ Max. Fluid Temp. = 150°C

Model 1157 90° Angle Adapter

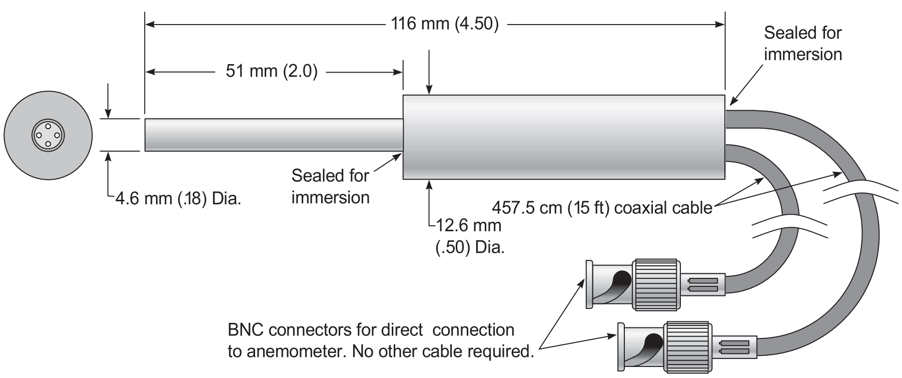


Right angle bend provides access to upstream points with straight probes.

Specify

+ 1157
+ 1157A (for use with Models
+ 1240 and 1247A
  probes only)

Model 1154 Dual Sensor Probe Support for Liquids



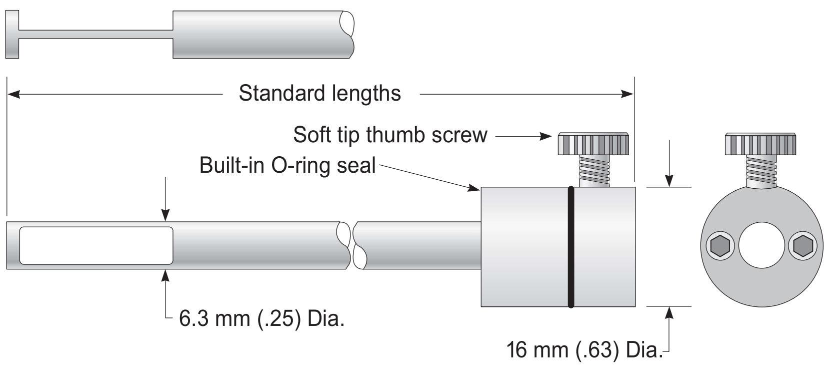
Small probe can be immersed for liquid flow applications.

Specify

+ 1154-15

PROBE ACCESSORIES

Model 1139 Shield With Window

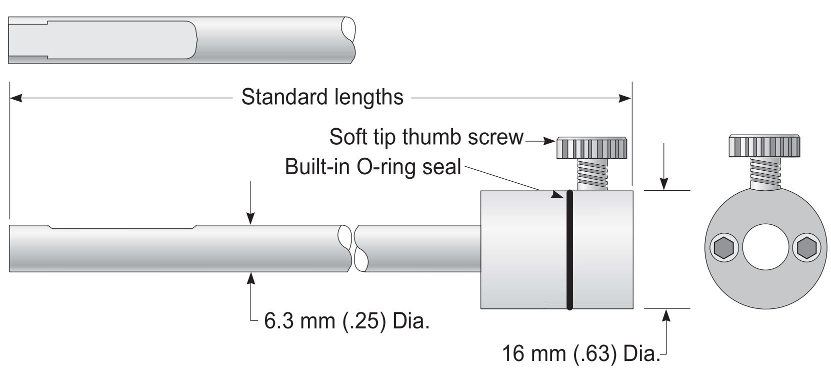


Completely protects sensor while providing opening for cross-flow measurements. Probe can be extended beyond end for unobstructed measurements. Fits Model 1150 Probe Supports.

Specify

+ 1139-6 for 152 mm (6 in.) length
+ 1139-18 for 457 mm (18 in.) length
+ 1139-36 for 915 mm (36 in.) length

Model 1160 High Temperature Probe Support

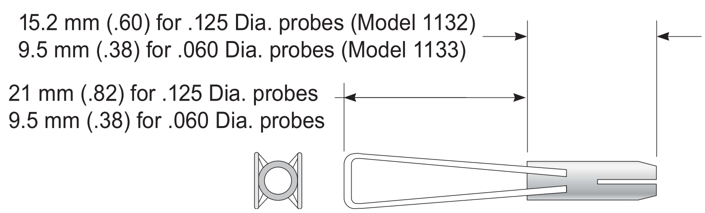


Protects probe when used as a shield, locks probe into socket when extended. Provides sturdy support for probe. Fits Model 1150 Probe Supports and most standard probes.

Specify

+ 1158-6 for 152 mm (6 in.) length
+ 1158-18 for 457 mm (18 in.) length
+ 1158-36 for 915 mm (36 in.) length

Model 1132 Wire Shield
Model 1133 Miniature Wire Shield

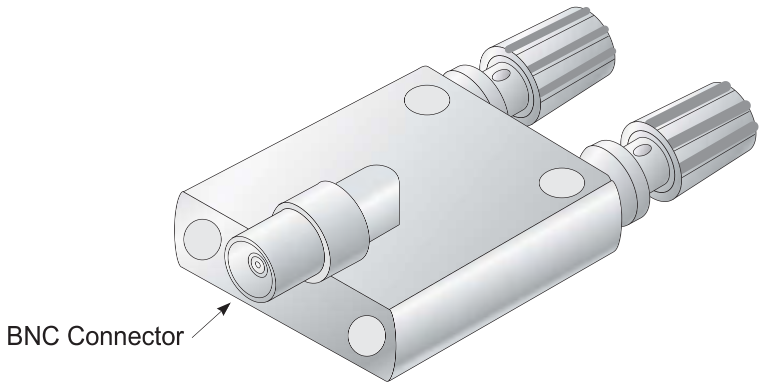


Protects probe from breakage while in use. Can be installed and removed as required using friction fit.

Specify

+ 1132 for 3.18 mm (1/8 in.) diameter probes
+ 1133 for 1.5 mm (.060 in.) diameter probes

Model 1108 BNC Subminiature Probe Adapter

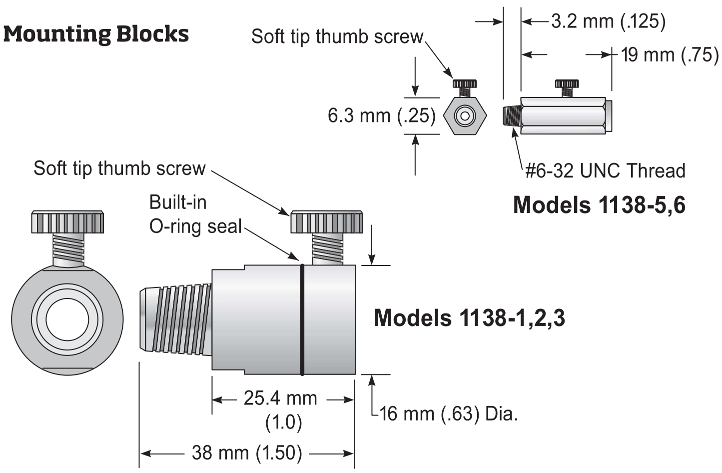


Adapts from probe wires to BNC connector for subminiature probes with wire leads.

Specify

+ 1108

Model 1138 Mounting Blocks

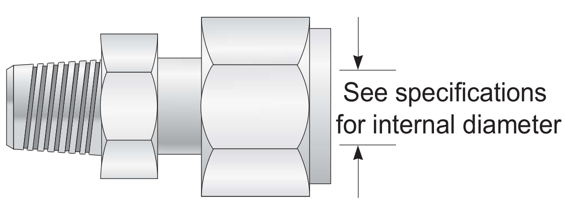


A sealing fitting for probe traversing and for mounting probe supports to the wall of a test section.

Specify

+ 1138-1 for .250 in. Prot. Sleeve-1/4 NPT
+ 1138-2 for .180 in. Probe Support-1/4 NPT
+ 1138-3 for .125 in. Standard Probe-1/8 NPT
+ 1138-6 for .035 in. Submin. Probe-6-32

Model 1137 Mounting Block



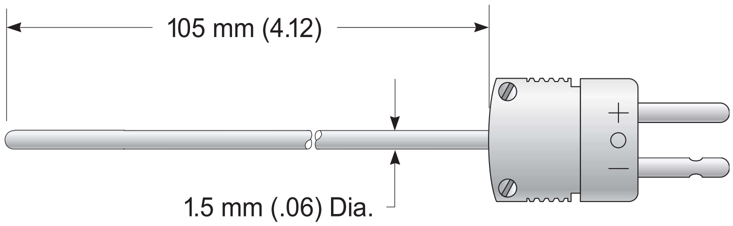
Sealing fittings for probe traversing and for mounting probe supports to the wall of a test section. Has nylon ferrules for higher pressure applications.

Specify

+ 1137-1 for .250 diameter, 1/4-18 NPT
+ 1137-2 for .180 diameter, 1/4-18 NPT
+ 1137-3 for .125 diameter, 1/8-27 NPT
+ 1137-4 for .060 diameter, 1/8-27 NPT

PROBE ACCESSORIES

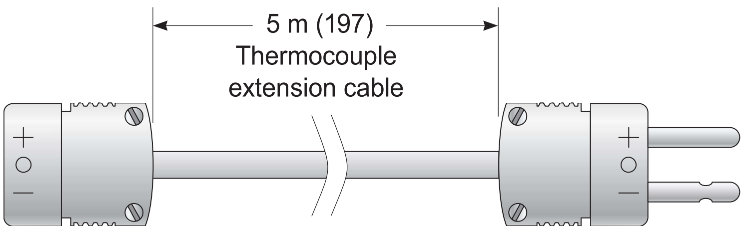
Model 1341 Thermocouple Probe



Measures temperature of measurement environment. Type-T copper-constantan.

Specify
+ 1341

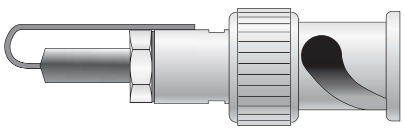
Model 1340 Thermocouple Extension Cable



Cable 5 m long connects Model 1340 Thermocouple to anemometer. Type-T copper-constantan.

Specify
+ 1340

Model 1304 Control Resistor



Model 1304 control resistors are used with bridges that have a 5 to 1 ratio, such as 1750 and 1050/1053/1054 anemometers.

Specify
+ 1304-XX
where XX is the resistance to the nearest 1 ohm. To determine the correct resistance, refer to equation 2 on page 22.

Model 10120 Hot Wire/Film Sensor Repair Kit

Includes equipment needed to attach hot wire or cylindrical film sensors designed for gas applications to needle supports. Kit includes soldering iron with spare tips, single-edge razor blades, soldering stand with clip, jeweler's broach, soft solder (400°F melting point), distilled water, brush, acid flux, and a file. A microscope or magnifier of about 10X to 20X is also recommended.

Specify

- 10120 for 110 VAC, 60 Hz
- 10120-1 for 220 VAC, 50 Hz

Model 10121 Hot Film Replacement Sensors

These are high-quality, alumina-coated hot film sensors (cylindrical elements for air only) for field replacement use. They are furnished in quantities of 10.

Specify

- 10121-10 for 0.025 mm (0.0015 in.) dia. with 0.5 mm (0.020 in.) sensor length
- 10122-20 for 0.05 mm (0.002 in.) dia. with 1.0 mm (0.040 in.) sensor length
- 10122-60 for 0.15 mm (0.006 in.) dia. with 2 mm (0.080 in.) sensor length

Model 10122 Hot Wire Replacement Sensors

These are high-quality, platinum-coated tungsten hot wire sensors for field replacement use, furnished in quantities of 12 on a card. The ends of the wires are plated to isolate the active sensor region.

Specify

- 10122-T1.5 for 0.0038 mm (0.00015 in.) dia. with 1.25 mm (0.050 in.) sensor length
- 10122-T2 for 0.005 mm (0.0002 in.) dia. with 1.25 mm (0.050 in.) sensor length

Model 10123 Wire for Hot Wire Sensors

This is the same high-quality, platinum-coated tungsten wire used in the Model 10122 but furnished on a spool in a 2-meter length.

Specify

- 10123-T1.5 for 0.0038 mm (0.00015 in.) dia. with 2-meter length of wire
- 10123-T2 for 0.005 mm (0.0002 in.) dia. with 2-meter length of wire

DETERMINING OPERATING RESISTANCE OF A SENSOR

Each TSI probe is furnished with complete sensor data showing the recommended operating resistance (Rop) of the sensor.

Fragile Sensors
To be opened only by user

Probe Model ________ Serial ________ TSI Ref. No. ________

Sensor No.	Probe RES at 0C R_0,Ω	R_{100}-R_0 Ω	Recommended Oper. RES R_{0p},Ω	Recommended Oper. Temp. T_{0p},C	Internal Probe RES R_{int},Ω
1					
2					
3					

Notes: 1. Control RES (If required)=(R_{0p}+R cable) x 5 on 5:1 BRIDGE
2. R_0=R sensor+R_{int}

Call 1-800-874-2811 for service. Made in U.S.A.

Example of Sensor Data Label

The operating resistance of the sensor determines the temperature at which the sensor will be operated. Operating resistances are calculated from sensor resistance data taken at 0°C (R_0) and 100°C (R_{100}-R_0) and include the internal probe resistance (R_{int}). The operating resistance listed with each probe corresponds to the recommended operating temperature of the sensor (T_{op}) which is also included with the probe. Sensors for use in air or other gases are usually run at temperatures of 250°C, while water sensors are run at 67°C. These sensor temperatures have been selected to optimize sensitivity and signal-to-noise ratio, and provide maximum sensor life. If a different sensor temperature is desired, it can be calculated from:

Equation 1

$$R_{op} = \frac{T_s\left(R_{100} - R_O\right)}{100°C} + R_O$$

where:

R_{op} = Operating resistance of the sensor (ohms)
T_s = Desired sensor temperature (°C)
R_{100}-R_0 = Sensor resistance change between 0°C and 100°C (ohms)
R_0 = Sensor resistance at 0°C (ohms)

The operating resistance of the sensor can be set with a variable resistance decade or with a fixed control resistor. The required control resistor value can be determined by:

Equation 2

$$R_{CR} = \left(R_{op} + R_c\right) \times 5$$

(for 5:1 bridge ratio)
where:

R_{CR} = Control resistor value (ohms)
R_c = Probe cable resistance, including probe support (ohms)

For TSI 1050 Anemometers with resistance decades, or for IFA 100, IFA 300, and FlowPoint™ Anemometers, the operating resistance can be set directly if the probe cable resistance is properly accounted for.

PROBE CALIBRATION

The probe current versus velocity curves* on page 23 show the sensitivity of various types of sensors. Velocity sensitivity is taken directly from the slope of the curve as amps per units of velocity. To convert from current sensitivity to bridge voltage sensitivity, use the following equation:

Equation 3

$$\frac{\Delta E_B}{\Delta V} = \frac{\Delta I_s}{\Delta V}\left(R_{op} + R_B\right)$$

where:

$\frac{\Delta EB}{\Delta V}$ = The slope of the calibration curve at the velocity of interest, proportional to the ratio of change in sensor current (ΔI_S) for a small change in velocity (ΔV) past the sensor.
E_B = Bridge voltage
V = Velocity
R_{op} = Sensor operating resistance
R_B = Bridge resistor in series with the sensor (10 ohms for IFA 300 STD Bridge)

The curves can also be used to determine the electrical power dissipated in the sensor or to estimate the approximate bridge voltage at a given velocity:

Equation 4

$$E_B = I_s\left(R_{op} + R_B\right)$$

where:

E_B = Bridge voltage
I_s = Sensor current
R_{op} = Sensor operating resistance
R_B = Bridge resistor

The sensor curves shown are valid only for the sensor resistance listed. For a different resistance sensor, correct the sensor current by:

Equation 5

$$I_{s_2} = I_{s_1}\sqrt{\frac{R_{op_1}}{R_{op_2}}}$$

where:

I_{s2} = New sensor current
I_{s1} = Sensor current from curve
R_{op1} = Sensor resistance listed on curve
R_{op2} = Actual sensor resistance

Sensitivity to Resistance Change

Often in anemometry, questions may arise regarding: 1) Effect of cable length on calibration; 2) "Noise" from slip rings and other types of "contact problems;" 3) Effects of resistance shifts of the sensor; 4) Stability requirements of other resistors in the bridge. These questions all relate to the effect of resistance changes on the output voltage. This can be expressed as:

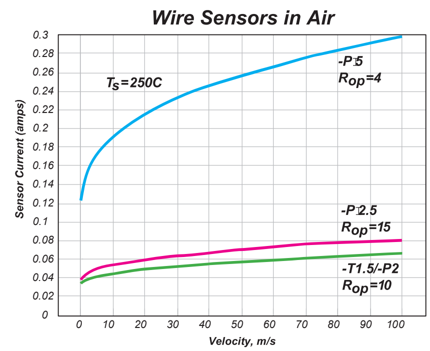
Equation 6

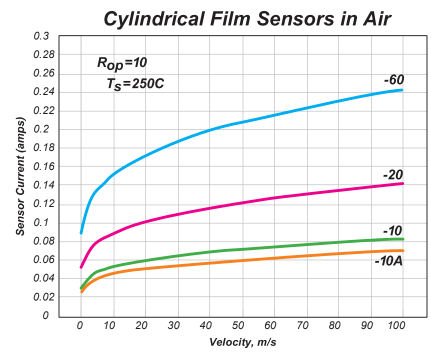
$$\frac{\Delta E_B}{\Delta R_{op}} = -\frac{I_s}{2}\frac{\left(R_{op}/R_B\right)\left(2R_{op}/R_e-1\right)+1}{\left(R_{op}/R_e\right)-1}$$

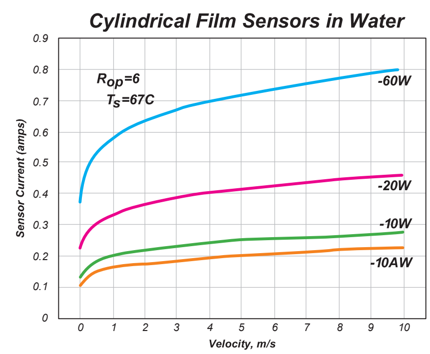
For example, if R_{op} = 9 ohms, R_e = 6 ohms, and R_B = 10 ohms, then:

$$\frac{\Delta E_B}{\Delta R_{op}} = -2.8\,I_s\left(volts/ohm\right)$$

From the sensor current curves at the right and equation (3), a resistance change can be related to velocity sensitivity.







Effects of Amplifier Drift

The following relationship gives the ratio of bridge voltage (output) change to a change in amplifier input voltage.

Equation 7

$$\frac{\Delta E_B}{e_b} = -\frac{1}{2}\left[1+\frac{R_B}{R_{op}}\right]\frac{\left(R_{op}/R_B\right)\left(2R_{op}/R_B-1\right)+1}{\left(R_{op}/R_e\right)-1}$$

Using the above example:

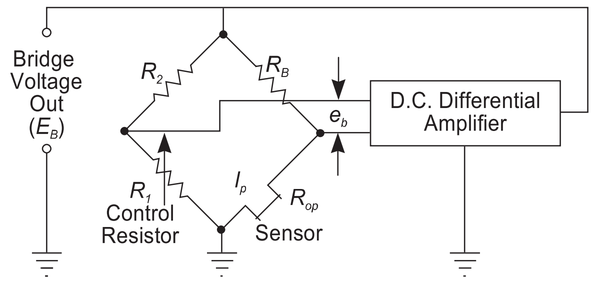
$$\frac{\Delta R_B}{e_B} = -3.63$$

Therefore, a change of 10 microvolts at the amplifier input (equivalent input drift for example) gives only 36.3 microvolts at the anemometer output for the assumed conditions. A constant temperature anemometer is inherently a very stable instrument.

Conduction Loss to Supports

The steady-state effects of conduction losses to supports have little influence on the mean velocity accuracy if the sensor is properly calibrated. Only when attempts are made to predict the calibration heat transfer equations will the steady state conduction to supports become a factor. In noncylindrical film sensors, the dynamic effects of nonsteady state heat conduction to the supporting structure can be significant, particularly in gases. For example, the high frequency (compensated) sensitivity can be less than half of that predicted by a steady-state calibration curve. The actual attenuation depends on many factors including the size and shape of the sensor and its environment. In general, the high heat transfer rates in water reduce this error to acceptable levels, while in gases a dynamic calibration is required for optimum results. It should be emphasized that this effect is usually negligible in both hot wires and cylindrical film sensors. This is because the conduction loss to the supports is small and the supports are a sufficiently large heat sink so their temperature change is small.

*Curves are for typical sensors. Actual sensors will vary.



Schematic of Constant Temperature Anemometer

Calibration Adjustments

Calibrations are made by plotting Bridge Voltage, E_B, as a function of Velocity and then fitting the data with a polynomial or exponential curve fit. If the calibration must be adjusted for use with a different bridge resistance, R_B, or cable resistance, R_c, it is useful to assume that the sensor current is constant (for a given velocity and sensor temperature). For convenience, internal probe resistance is included in sensor resistance data, but probe support resistance can be measured or nulled out and should be included with cable resistance, R_c. Then we can calculate a new bridge voltage for each velocity.

Equation 8

$$I_s = \frac{E_B}{\left(R_B + R_c + R_{op}\right)}$$

and so:

$$E'_B = E_B \frac{\left(R'_B + R'_c + R_{op}\right)}{\left(R_B + R_c + R_{op}\right)}$$

Temperature Sensitivity

Bridge Voltage is corrected for ambient temperature changes as follows. A reasonable assumption is that

$$\frac{E_B^2}{\left(T_s - T\right)}$$

is constant for a given velocity as temperature changes. Therefore, we can predict a bridge voltage E_B' for a new temperature, T', as follows.

Equation 9

$$E_{B'} = E_B \left[\frac{T_s - T'}{T_s - T}\right]^{1/2}$$

Directional Sensitivity of Cylindrical Sensors

The following provides a very brief introduction to techniques for measurements with cylindrical thermal sensors. To simplify this presentation, it is assumed that the sensor is sufficiently long so that the following approximation can be used:

Equation 10

$$V_{eff} = V \cos \alpha$$

In other words, the effective cooling velocity past the sensor varies as the cosine of the angle between the sensor axis and the velocity vector. At 90°, V_{eff} = V and at 0° V_{eff} = 0. It should be noted that in the ideal case, the sensitivity remains constant as the velocity vector moves around the sensor at a constant angle, a, to the sensor axis.

Single Sensor Oriented Perpendicular to the Mean Flow

Let the mean flow be represented by V_1 and the fluctuations represented by v_1, v_2, and v_3 where v_2 represents the fluctuations in the direction parallel to the sensor and v_3 represents the fluctuations in a direction perpendicular to v_1 and v_2. The effective velocity measured will be:

Equation 11

$$V_{eff} = \sqrt{\left(\overline{V_1} + v_1\right)^2 + v_3^2}$$

If we neglect v_3, then:

$$\overline{V_1} = \overline{V} = \overline{V_{eff}}$$

and

$$\sqrt{\overline{v_1^2}} = \sqrt{\overline{v_1^2}}$$

The value of V_1 is the average value while

$$\sqrt{\overline{v_1^2}}$$

is the rms value.

When

$$\sqrt{\overline{v^2}}/\overline{V} = 0.2$$

(= 20% turbulence intensity), the error due to ignoring v_3 is about 2% for isotropic, normally distributed, and normally correlated turbulence.† The mean velocity error is also about 2%.

X Probe (Two cylindrical sensors oriented at 90° to each other)

The X probe is used to measure two velocity components. Writing the equations for the effective velocity for the two sensors "A" and "B" with the mean velocity in the plane of the two sensors V_3 = 0 and $\overline{a_1}$ = the angle between V_1 and sensor B gives:

Equation 12

$$V_{A,eff}^2 = \left(V_1 \cos \alpha_1 - V_2 \sin \alpha_1\right)^2 + v_3^2$$

$$V_{B,eff}^2 = \left(V_1 \sin \alpha_1 + V_2 \cos \alpha_1\right)^2 + v_3^2$$

If the sensors are further aligned so a_1 = 45° and v_3^2 is assumed negligible, then rearranging the above equations gives:

Equation 13

$$V_1 = 2^{-1/2}\left(V_{A,eff} + V_{B,eff}\right)$$

Finally, if the sensors are aligned so that $\overline{V_2} = 0$ and $\overline{V_1} = \overline{V}$, then:

Equation 14

$$\overline{V} = 2^{-1/2}\,\overline{\left(V_{A,eff} + V_{B,eff}\right)}$$

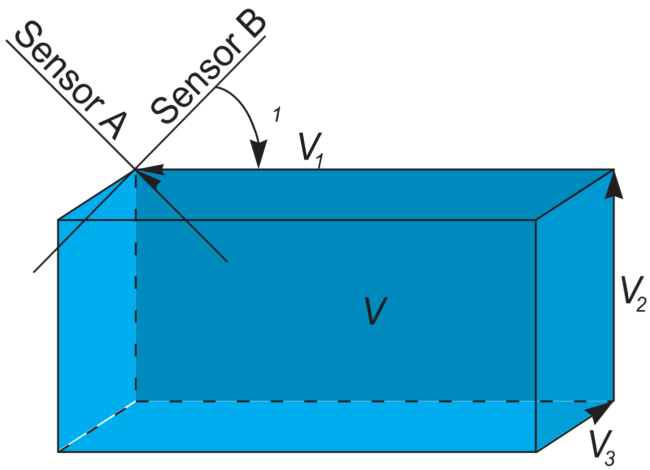
$$\overline{v_1^2} = 2^{-1}\,\overline{\left(v_{A,eff} + v_{B,eff}\right)^2}$$

$$\overline{v_2^2} = 2^{-1}\,\overline{\left(v_{A,eff} - v_{B,eff}\right)^2}$$

$$\overline{v_1 v_2} = 2^{-1}\,\overline{\left(v_{A,eff} + v_{B,eff}\right)\left(v_{A,eff} - v_{B,eff}\right)}$$

Neglecting v3 gives an error of about 8% when the turbulence intensity is 20%, with the same flow field as discussed for the single wire.†

The above is given here to provide some insight into how single sensors and X probes are used and the limitations at high turbulence intensities. Refinements of the equations as well as other considerations are contained in the extensive literature on thermal sensors contained in the Freymuth bibliography.



Configuration of X-probe.

Nomenclature

E_B = bridge voltage output
ΔE_B = small change in bridge voltage output
e_b = small voltage change at amplifier input
f = frequency, (Hz)
I_s = current through sensor (amps)
DI_s = small change in sensor current
R_c = probe cable resistance (includes probe support resistance, but not internal probe resistance)
R_{CR} = control resistor value
R_e = resistance of sensor at ambient (environment) fluid temperature (ohms)
R_o = sensor resistance at 0°C
R_{op} = resistance of sensor at operating temperature
DR_{op} = small change in sensor resistance
R_B = bridge resistor in series with the sensor, 10 ohms for FlowPoint, IFA 100, IFA 300 except 2 ohms for IFA 100, IFA 300 Hi Power Bridge; 40 ohms for Model 1053B, 1054A, 1054B, and #1 Bridge on Model 1050; 10 ohms for #2 Bridge on Model 1050 and 2 ohms on #3 Bridge on Model 1050; 20 ohms for Model 1750.
T = fluid temperature
T_s = sensor operating temperature (°C)
V = fluid velocity past sensor
ΔV = small change in fluid velocity past sensor
V_1, V_2, V_3 = orthogonal components of V relative to flow facility
V_{eff} = effective cooling velocity past sensor (equivalent value of VN)
$VA_{,eff}$ = effective velocity as seen by sensors (and similarly for sensor B)
v = small fluctuations in velocity V
a_1 = angle between velocity vector and sensor axis

†S.P. Parthasarathy and D.J. Tritton, "Impossibility of Linearizing Hot-Wire Anemometer for Turbulent Flows," AIAA J., vol. 1, pp. 210-1211, 1963.

SPECIFICATIONS

Hot Wire and Hot Film Sensors

Hot Wire

Type	Dash No. Designation Suffix in Probe No.	Diameter (D) of Sensing Area or Width in m (in.)	Length (L) of Sensing Area in mm (in.)	Distance Beween Supports in mm (in.)	Maximum Sustained Ambient Temperature (C°)	Maximum Sensor Operating Temperature (C°)	Temperature Coefficient of Resistance (C°)
Tungsten Platinum Coated	-T1.5	3.8 (0.00015)	1.27 (0.05)	1.52 (0.06)	150	300	0.0042
Platinum	-P2	5.1 (0.0002)	1.27 (0.05)	1.27 (0.05)	300	800	0.00385
Platinum Iridium (Alloy)	-PI2.5	6.3 (0.00025)	1.27 (0.05)	1.27 (0.05)	300	800	0.0009
Platinum Iridium (Alloy)	-PI5	12.7 (0.0005)	1.27 (0.05)	1.27 (0.05)	300	800	0.00094

Hot Film Gas

Type	Dash No. Designation Suffix in Probe No.	Diameter (D) of Sensing Area or Width in m (in.)	Length (L) of Sensing Area in mm (in.)	Distance Beween Supports in mm (in.)	Maximum Sustained Ambient Temperature (C°)	Maximum Sensor Operating Temperature (C°)	Temperature Coefficient of Resistance (C°)
Platinum	-10A	25.4 (0.001)	0.25 (0.01)	0.76 (0.03)	150/300	425	0.0024
Platinum	-10	25.4 (0.001)	0.51 (0.02)	1.27 (0.05)	150/300	425	0.0024
Platinum	-20	50.8 (0.002)	1.02 (0.04)	1.65 (0.065)	150/300	425	0.0024

Hot Film Liquid

Type	Dash No. Designation Suffix in Probe No.	Diameter (D) of Sensing Area or Width in m (in.)	Length (L) of Sensing Area in mm (in.)	Distance Beween Supports in mm (in.)	Maximum Sustained Ambient Temperature (C°)	Maximum Sensor Operating Temperature (C°)	Temperature Coefficient of Resistance (C°)
Platinum	-10AW	25.4 (0.001)	0.25 (0.01)	0.76 (0.03)	30	67	0.0024
Platinum	-10W	25.4 (0.001)	0.51 (0.02)	1.27 (0.05)	30	67	0.0024
Platinum	-20W	50.8 (0.002)	1.02 (0.04)	1.65 (0.065)	30	67	0.0024

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†S.P. Parthasarathy and D.J. Tritton, "Impossibility of Linearizing Hot-Wire Anemometer for Turbulent Flows," AIAA J., vol. 1, pp. 210-1211, 1963.

UNDERSTANDING, ACCELERATED

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APPENDIX C

Source Test Protocol Evaluation, August 27, 2024

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

SCIENCE & TECHNOLOGY ADVANCEMENT * SOURCE TEST ENGINEERING BRANCH

SOURCE TEST PROTOCOL EVALUATION

S/T ID:	**P24228**
SCAQMD ID:	*FACILITY ID NO.* **119219**
COMPANY:	**Chiquita Canyon Landfill, LLC, Castaic**
EQUIPMENT:	**Landfill Leachate and Condensate Storage Tanks - Vapor Sampling** **Tank Farm #7** **Tank Farm #9** **Flare Station Inlet**
TEST LOCATION:	**29201 Henry Mayo Dr., Castaic**
REQUESTED BY:	**Baitong Chen (Memo Dated July 24, 2024)**
TYPE OF TEST:	**PERFORMANCE/COMPLIANCE PROTOCOL**
DOCUMENT DATE:	**July 11, 2024**
REASON FOR TEST:	*(TESTING SUBJECT TO THE FOLLOWING RULE, PERMIT, OR SPECIFIED CONDITIONS):* - Priority handling requested due to Abatement Order (Case 6177-4). Testing per OA Condition 72. Testing is intended to determine the vapor emissions from the landfill leachate and condensate storage tanks within the tank vents/manifolds, gas headers, and flare station inlet.
REQUESTED EVAL:	**H2S, TRS, TO-15**
TEST FIRM:	**Montrose Air Quality Services, LLC**
STE EVALUATOR:	**Rodney Davis** *EXT:* **2206** *REVIEW DATE:* **August 27, 2024**

OVERVIEW OF EVALUATION:

OVERALL CONFIDENCE IN SOURCE TEST PROPOSAL:	☐ **ACCEPTABLE**	☒ **CONDITIONALLY ACCEPTABLE**	☐ **UNACCEPTABLE** ☐ **NOT REVIEWED**
DEFICIENCIES IDENTIFIED:	• Deficiency noted concerning the proposed sampling location(s) and/or representativeness with respect to process and required testing		
MODIFICATIONS OR REMEDIAL MEASURES REQUIRED:	• There are some important reminders concerning the proposed testing. • This source test proposal must be modified to address the deficiencies described in the following section of this evaluation, and the source testing which incorporates these modifications may proceed without further discussion.		

(REFER TO THE NEXT SECTION FOR A COMPLETE DISCUSSION OF THESE DEFICIENCIES)

S P E C I F I C R E Q U I R E M E N T S

This source test protocol has been reviewed by the Source Test Engineering Branch staff. The following item(s) specifically explain the required modifications to the existing source test protocol which must be implemented, or items requiring further discussion or explanation, before testing can proceed:

- ☒ Completeness of Protocol
- ☒ Representativeness of Data & Process
- ☒ Rule/Permit Fulfillment
- ☒ Sampling & Analytical Methods
- ☒ Quality Assurance
- ☒ Calculations

COMPLETENESS OF PROTOCOL

- The report shall be submitted in a digital and/or hardcopy format.

- Each page of the final test report (including raw analytical and field data, as well as other third-party reports) must have a unique and sequential page number which can be referenced in future correspondences.

REPRESENTATIVENESS OF DATA & PROCESS

- The final report shall include pictures of each source location and its corresponding sample location.

- The tester shall adhere to the following requirements when measuring velocity per SCAQMD Methods 1-4:
  - Cyclonic flow checks must be performed using an S-Type Pitot tube, and the instrument used for measuring cyclonic flow angles must be documented in the test report;
  - Sample ports shall be located according to SCAQMD Method 1.1;
  - As applicable, calibration data for the sling psychrometer shall be included with the test report.

- As stated in section 2.1 of the protocol, if low flow rates (delta P less than 0.05 inches of w.c.) are detected during or before the source test program, a standard or "S" type pitot tube that meets Method 2.1 is to be required along with a calibrated digital manometer. Calibration documentation must be included with the test report to validate the accuracy of the differential pressure gauge.

- As a reminder for velocity pressure measurements (as described in Section 2.1.2 of South Coast AQMD Method 2.1) using typical 10-inch water column inclined-vertical manometers and magnehelics readings are not considered accurate if:
  - a) Average readings are <0.05" w.c.;
  - b) >10% of points are <0.05" w.c. (12 or more traverse points); and
  - c) >1-point is <0.05" w.c. (traverses of less than 12 points).

S P E C I F I C   R E Q U I R E M E N T S

- Per section 5.0 Process Equipment Information, process data to be monitored will include landfill gas throughput and report wellhead vacuum and tank pressures, if applicable.

- Notification of the source test shall be made to the South Coast AQMD at least ten days prior to the source test. Notification shall be made to Rodney Davis (Phone: (909) 396-2206, email: rdavis@aqmd.gov), Baitong Chen, bchen@aqmd.gov; Nathaniel Dickel, ndickel@aqmd.gov; Christina Ojeda, ojeda@aqmd.gov and shall include the facility name, ID number and address, and the date and time of the source test.

RULE/PERMIT FULFILLMENT

- Testing must be conducted pursuant to the following Order of Abatement Conditions:

All of the above requirements have been addressed in this protocol and are satisfactory as proposed, or as modified as discussed in this review. The source test report emission information must also be formatted to satisfy the above Rule/Permit Conditions.

SAMPLING & ANALYTICAL METHODS

- Pressure/vacuum as well as flow control rate into the TO-15 canister are to be recorded on the canister field test data sheet as indicated by the sampler vacuum/pressure gauge and flow control device. Canisters and gauges should be tested clean and leak tight.

- South Coast AQMD Method 307-91 for H2S and/or SO2 requires samples to be analyzed the same day or within 24 hours of collection in duplicate.

- Speciated volatile organic compounds sampled by EPA Method TO-15 must report all compounds listed in Tables 1 and 2 of Appendix D of the test method.

QUALITY ASSURANCE

- All applicable pieces of source test and process equipment used directly or indirectly for measurement of source test emission data must be calibrated, and the calibrations included in the final report (this includes gas meters, Pitot tubes, pressure gages, nozzles, temperature devices, calibration gases, fuel usage meters, totalizers, etc.).

- Where appropriate, field blanks, reagent blanks and recovery spikes must be performed, and the information submitted with the source test report. Only reagent blanks may be deducted for emission calculations.

- All raw data field data sheets, as well as recorder strip charts, must accompany the test report.

- Where laboratory instrument analysis is required, instrument raw strip charts, calibrations and standards, and limit of detection must be included in the source test report. This also includes equipment transfer and “chain-of-custody” form clearly describing all equipment and laboratory ID numbers, dates and times, required analysis, and the signature/initials of persons involved in transfers. TCA analyses must also include trap burnouts from the previous test, if applicable.

- The terms "non-detect" or "non-detectable" are no longer used for emission reporting purposes. Instead, non-detectable results are reported with respect to the limit of detection of the analytical instrument or method (e.g. report "<10 micrograms/liter", if detection limit is 10 micrograms/liter). Non-detectable emission results must have supporting documentation to show that acceptable sample volume was collected pursuant to rule or permit limits and analytical method limits of detection.

- The Chain-of-Custody forms for transferring the SCAQMD Method 25.3 vial (midget impinger) samples to the analytical laboratory must include the temperature of the vials at the time of transfer.

- Equipment used by the source testing contractors must adhere to the Chapter III calibration and maintenance requirements of the Source Test Manual.

CALCULATIONS

- All calculations concerning intermediate process, emission, and/or flow information must be shown and included in the final report. This also applies to calculations concerning laboratory analyses emission calculations.

B O I L E R P L A T E   R E M A R K S

(Do Not Include in Report)

FINAL TEST REPORT

The final Source Test Report must include the following information:

1. Signed "Statement of Non-Conflict as an Independent Laboratory" (SCAQMD Rule 304(k)) and CARB Lab Approval or SCAQMD Lab Approval Program (LAP) document (if applicable).

2. A brief opening statement identifying the Facility I.D., the equipment A/N, P/O, or Device I.D. and the reason(s) for testing (applicable rules permit conditions, etc.). Include a copy of the Permit-to-Construct, Permit-to-Operate, or Facility Permit. Also identify the test dates, the personnel on hand for the test, names, titles and phone numbers of responsible test firm and facility personnel.

3. A summary of the Source Test results, including applicable rules and permit conditions (show allowable standards) and source test data properly formatted to satisfy these requirements.

4. A brief process description. Indicate equipment operation during testing; as well as any other information which may influence the final report.

5. A "self-critique" of anything that transpired during the test which you feel is useful in the interpretation of the test results.

6. A simple schematic diagram of the process, showing the sampling location, with respect to the upstream and downstream flow disturbances. Also include a cross-sectional diagram of the stack or duct at the sampling location, depicting the sampling points with respect to compass direction.

7. The sampling and analytical procedures. Be specific about all aspects of sampling and analysis. Include diagrams of test equipment and methods.

8. Complete raw field data, including production data indicative of the testing interval, lab analyses, and the test results (show all calculations).

9. Current calibration data regarding all sampling and measuring equipment utilized during testing. This also includes all laboratory calibrations, as well as facility fuel meter calibrations. (See SCAQMD Source Testing Manual, Chapter III or "Quality Assurance Handbook For Air Pollution Measurement Systems", Vol..III, U.S. EPA-600/4-77-0276).