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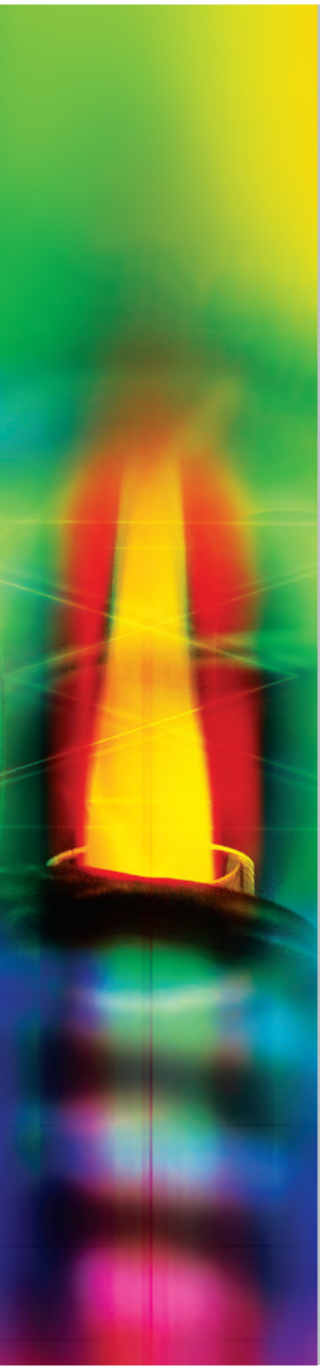


Comparing ICP-OES Analyzers' Plasma Interfaces: Axial, Radial, Dual, MultiView, and New Dual Side-On

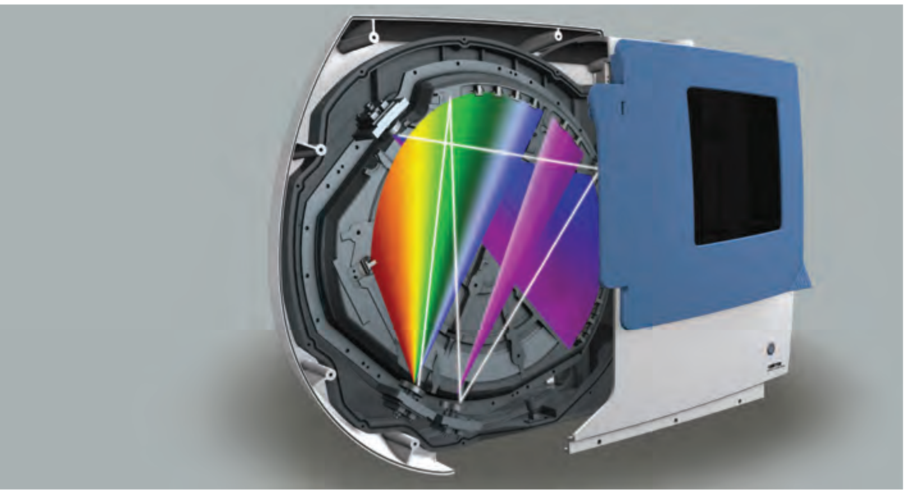
Introduction

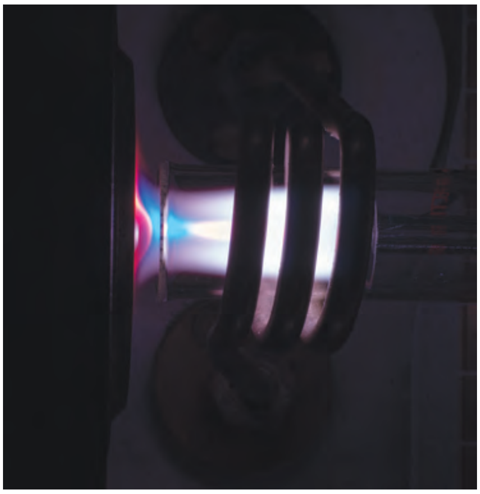
Inductively coupled plasma optical emission spectrometry (ICP-OES) instruments have become the analyzers of choice for a wide array of industrial, environmental, and research tasks.

Their technologies are complex. Manufacturers offer many competing claims about each product's sensitivity, stability, speed, and more.

One key differentiator: how spectrometers handle optical plasma observation. Understanding concepts such as axial view, radial view, and dual view is critical to deciding which instrument to purchase for which analysis. This report can help clear up any confusion. It briefly defines different plasma viewing technologies, compares their strengths and weaknesses, and discusses typical applications.

It also highlights recent developments in plasma viewing technology that significantly alter the equation — and may change users' minds about which instrument to select.





Inside view: diffracting light, the optical system separates the wavelengths emitted in the plasma.

TECHNOLOGIES IN VIEW

In the ICP-OES method, when a sample is excited within an analyzer's high-temperature argon plasma, given spectral wavelengths are characteristically emitted by specific elements. Emitted light reaching an optical system is resolved into these separate wavelengths by means such as diffraction gratings. The light is finally directed onto a detector array that quantifies light intensities at these wavelengths. Thus users can identify and measure each element in the sample.

This paper concentrates on the plasma viewing designs used in different types of ICP-OES spectrometers.

AXIAL VIEW

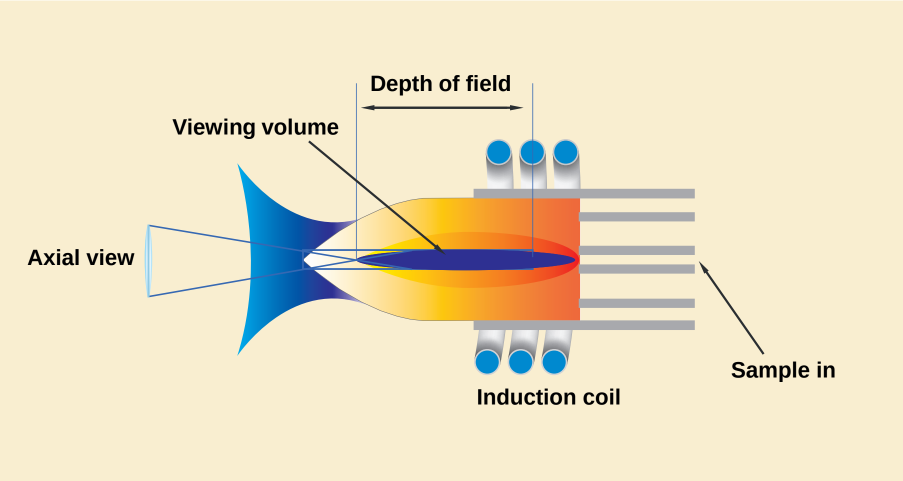
An axial-view system "looks" from end to end of the plasma's entire axis. It basically observes all phenomena in the excitation channel.

Observation is usually accomplished via an optical interface next to the plasma. The interface releases argon gas to cool itself, and to deflect parts of the plasma from the interface's opening, through which light passes into the optical chamber.

This axial-view design allows a large amount of light into the optical system, and thus makes a relatively large volume of information available to process. For many analyses, this is a crucial benefit, leading to maximum sensitivity in detecting trace-element emissions.

However, all that light can contain more than emissions from elements of interest. It may also include background emissions. The light may be influenced by matrix interferences such as the easily ionized element (EIE) effect. These can degrade analytical accuracy. Example: in environmental samples, they can influence the measurement of alkali elements such as lithium, sodium, and potassium, as well as earth alkali elements such as magnesium or calcium.

Finally, axial-view systems can feature a horizontal plasma torch. This can increase challenges when measuring samples with high amounts of total dissolved solids (TDS) or with organic solutions.



Taking the long view:
axial plasma observation.

When to use axial view

Axial-view systems are best applied when you require the highest possible sensitivity, rather than the best precision. Their foremost asset: the lowest limits of detection possible using ICP-OES.

Until recent years, this advantage was often decisive. Axial-view detection limits frequently surpassed radial-view performance by a factor of 10. (See "Radial view" section below.) Many trace element analyses in industry, research, or academia could be accomplished only by axial-view spectrometers.

However, users looking to replace their older axial-view models will find that performance of newer radial-view models has improved significantly. Yet axial-view performance is only incrementally better. Today, axial detection limits are perhaps 2x-3x lower than (and thus still somewhat superior to) radial detection limits.

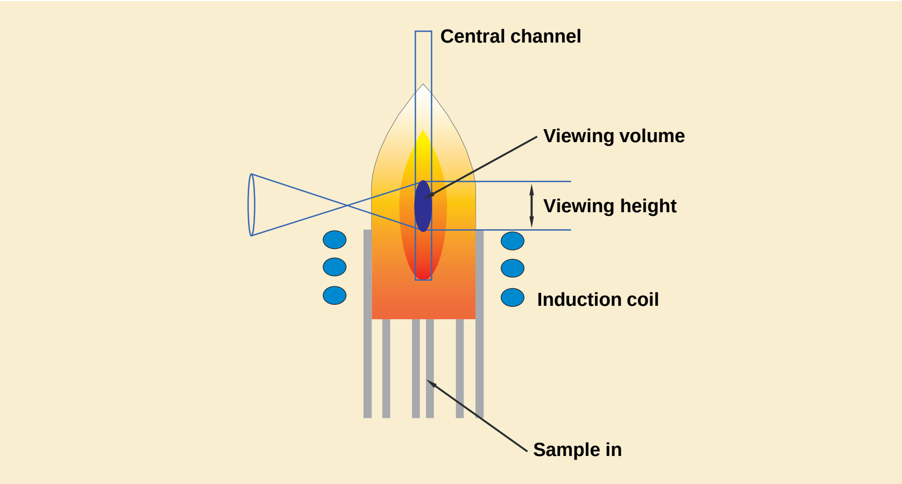
Also, axial models balance their one strength with key weaknesses. Their lower stability and matrix tolerance compared to radial-view models render them less suitable for high-TDS or organic samples. Finally, axial-view instruments require more complex designs that add extra maintenance, cleaning, and other costs.

Typical axial-view uses

Choose axial-view analyzers when achieving the lowest possible limits of detection is paramount. These are popular with users performing certain environmental as well as some industrial analyses.

Example applications:

- Trace metals in water (environmental)
- Trace metals in other kinds of material (for chemical, metal, or pharmaceutical industries, etc.)
- Trace metals in waste water and other effluents



Viewing just a slice of light:
radial plasma observation.

RADIAL VIEW

A radial-view system looks across the plasma. It sees only a relatively narrow cross section of light, rather than light from the whole length of the excitation channel.

With less light to process, a radial system can't match the sensitivity of an axial system in detecting trace elements.

However, by observing less light in total, a radial view also reduces or eliminates certain background emissions and matrix interferences. (Its higher tolerance for challenging matrices is also due to the use of a vertical plasma torch.) So it suffers less from noise than axial systems, and usually offers higher analytical precision.

When to use radial view

Basically, radial-view design favors precision over sensitivity. While they can't reach the very lowest detection limits promised by an axial-view or dual-view system (see "Dual-view" section below), today's best radial models have considerably narrowed the gap.

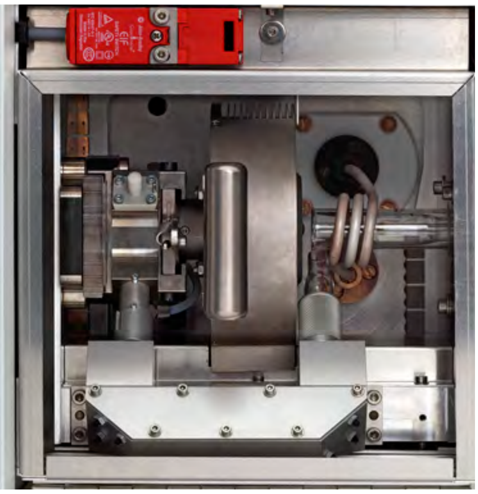
Users prefer radial models when seeking higher stability and especially higher matrix tolerance than with axial-view or dual-view models. Radial-view systems are also simpler and more robust. They require less maintenance and cleaning than their counterparts.

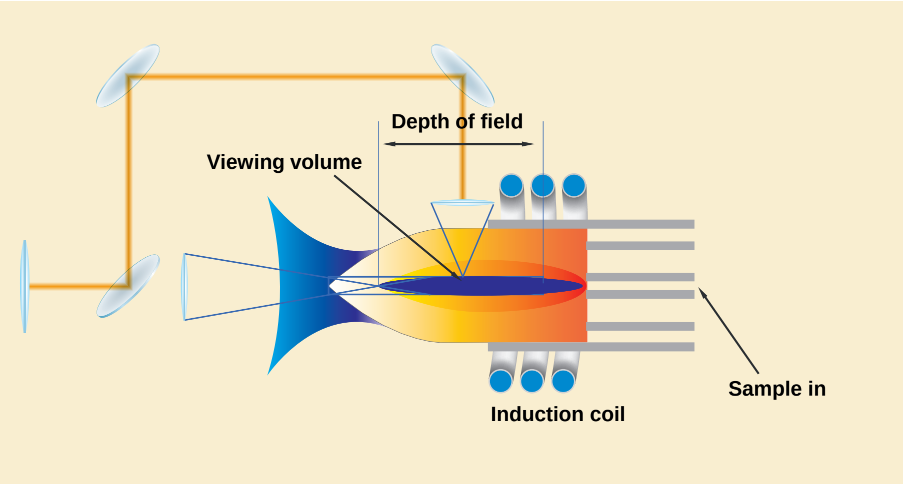
Typical radial-view uses

Radial-view systems are usually the instruments of choice for analyzing samples with the most difficult matrices. The best models deliver good performance at higher parts per billion (ppb) to parts per million (ppm) elemental concentration levels. They are popular with users performing most environmental analyses, as well as a wide range of industrial testing.

Example applications:

- High salts
- High TDS
- Wear metals in oils
- Organic solutions





Always optimized for one view or another:dual- view plasma observation.

DUAL-VIEW

Offering both radial and axial plasma observations, a dual-view system is designed to achieve the benefits of both. However, almost all current models must compromise this goal, favoring one view or the other.

Build details differ among major manufacturers. Today, dual-view ICP-OES analyzers fall into two major categories:

Axially optimized dual-view

These systems provide direct axial observation of the plasma, while utilizing periscopes or other means to achieve an added radial view. They thus offer full axial-view sensitivity. However, since up to 15% of analyzable light may be lost with each additional reflection, their radial view is somewhat compromised. Where background emissions or matrix interferences might afflict a dedicated axial system, these models can — sequentially or simultaneously, depending on the vendor — mitigate these effects with their radial views. This mode provides some of the precision of a dedicated radial system, while reducing or eliminating matrix effects.

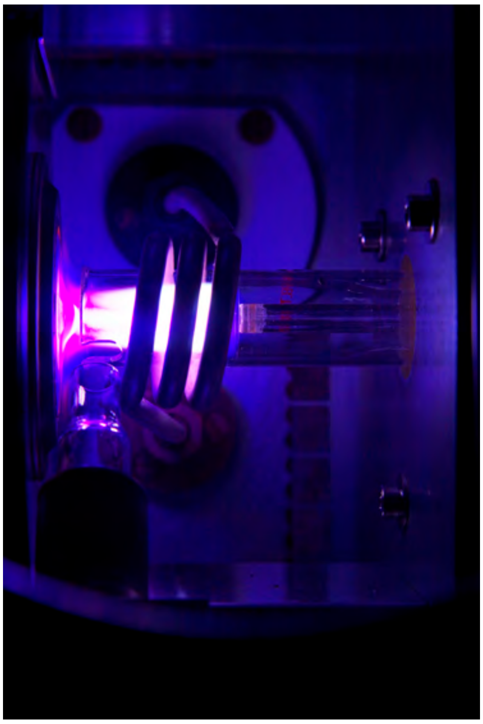
Radially optimized dual-view

These dual-view systems favor radial observation. They can provide full radial-view precision with minimal background emissions or matrix interferences. Their axial mode can also deliver good but not exceptional sensitivity.

Vertical-torch dual-view

For example, one manufacturer offers a system with a vertical plasma torch and a direct radial view, plus an axial view supplied via several mirrors in a periscope optic mounted just above the plasma. This approach may even furnish simultaneous observation of the plasma both axially and radially, in a single measurement. A specialized interference filter lets the user “block out” wavelengths above or below 500 nanometers (nm), depending on the sample.

The design has several advantages. It can eliminate EIE effects, and provide enough sensitivity to measure fairly low levels of certain challenging elements such as toxic metals (lead, cadmium, mercury, chromium, etc.).



However, the periscope's three additional reflections reduce light throughput significantly. This compromises the main function of an axial-view mode: sensitivity. There's decreased light transmission in the 200 nm range, and none below 185 nm. Thus this vertical-torch dual-view instrument cannot achieve the exceptional sensitivity of a late-model analyzer with a truly uncompromised axial view.

Also, this system cannot always eliminate all unwanted wavelength ranges. So background emissions and interferences may further degrade analyses.

Finally, positioning the axial interface just above the plasma can produce other problems. Particularly with samples containing high TDS or organic materials, the argon flow from the interface can "blow" contaminants back down into the plasma, skewing accurate analysis. And the high thermal stress on this interface may cause greater component wear, necessitating more frequent maintenance and replacement.

When to use dual-view

Laboratories that regularly undertake analyses requiring high sensitivity, as well as labs that need to analyze sample matrices where matrix effects (e.g., EIE) negatively influence the result for certain elements (e.g., alkalis), usually select dual-view ICP-OES analyzers. This includes users who often process samples covering a wide variety of applications, or who can't be sure what they may encounter. These instruments are popular with users conducting academic research, as well as those performing some industrial analyses.

Dual-view analyzers come at a slightly higher cost than dedicated axial-view or radial-view models (which tend to share similar price points.) They're also relatively complicated devices that require a fairly high degree of maintenance and cleaning.

Typical dual-view uses

Again, dual-view designs echo the pros and cons of their base technologies. Models optimized for axial plasma observation exhibit very high sensitivity, while their precision approaches can't match that of the best dedicated radial-view systems. Models based on radial approaches provide the greatest precision, but less sensitivity.

Example applications for axially optimized dual-view:

- Trace metals in water (environmental)
- Trace metals in other material (for chemicals, metals, pharmaceuticals, etc.)
- Trace metals in waste water and other effluents

Example applications for radially optimized dual-view:

- High salts
- High TDS
- Wear metals in oils
- Organic solutions

Dual-view: not for everyone

Some vendors recommend dual-view models to most or all of their customers, no matter what the application. This may be ill-advised.

First, remember that almost all dual-view designs share a bias toward either axial-view or radial-view performance. Only one view can utilize the direct light path; the other is compromised.

So dual-view models optimized for axial view utilize periscopes or other optical subsystems to acquire radial light. The observed plasma volume plus amount of light captured — and resulting detection limits and precision — are always less than those achieved by a dedicated system with a full radial view.

Of course, for a dual-view device optimized for radial view, the opposite limitations apply.

Laboratories should carefully evaluate their anticipated application profiles with their spectrometer supplier. The number of labs that frequently encounter unexpected or unknown samples is relatively small. Also, users may find that the great majority of the materials they're called upon to analyze clearly suit the operating parameters of either axial or radial plasma observation. In these cases, a dedicated instrument may provide the best possible fit.

For labs that often process samples covering a wide variety of applications, and for those that can't be sure what they might encounter, dual-view spectrometers may be an appropriate choice. Users should be aware of both their benefits and their limitations.

BEYOND DUAL-VIEW DRAWBACKS

MULTIVIEW

One fairly recent approach transcends almost all dual-view disadvantages.

MultiView technology is available in one version of the top-of-the-line SPECTRO ARCOS analyzer. It's the only ICP-OES instrument that offers both plasma views without bias or compromise.

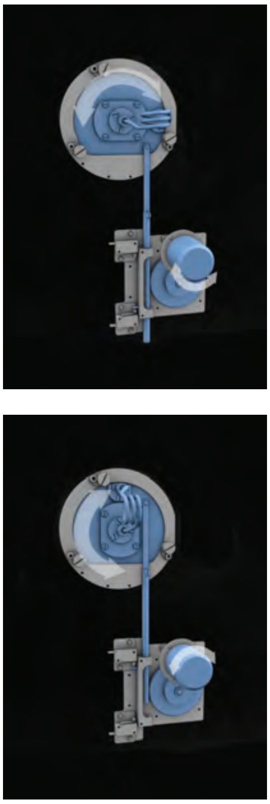
The sequential MultiView approach eliminates the use of added mirrors or periscopes. Instead, a user who typically uses

1) Simply remove radial torch and interface

2) Rotate load coil into desired horizontal orientation

3) Install axial torch and interface

4) Reconnect sample introduction system



Mechanically switching between two full views: MultiView plasma observation.

radial mode, for example, can measure a sample that needs extreme sensitivity simply by shifting the direction of the plasma torch into axial orientation. This relatively simple mechanical changeover takes about 90 seconds.

So this single instrument can offer academic researchers, environmental labs, and industrial users full radial precision and full axial sensitivity, as well as unmatched precision, dynamic range, and matrix compatibility. It's the equivalent of buying two dedicated, fully optimized analyzers in one.

Example applications for MultiView include the following.

- Trace metals in water (environmental)
- Trace metals in other materials (for chemicals, metals, pharmaceuticals, etc.)
- Trace metals in waste water and other effluents
- High salts
- High TDS
- Wear metals in oils
- Organic solutions

DUAL SIDE-ON INTERFACE (DSOI)

When it comes to plasma viewing, "dual" usually means offering both radial and axial views. However, with SPECTRO's new DSOI technology, it refers to a single view — but one that's effectively doubled.

This design is introduced in the new mid-range SPECTROGREEN analyzer, which is optimized for environmental analyses. It uses a vertical plasma torch, observed via a new variety of direct path radial-view technology.

In a DSOI system, an optical interface on one side of the plasma captures the amount of emitted light normal for radial observation, and conveys it into the optical system. But the concave mirror of a second interface on the other side captures additional emission light. This extra light — and added spectral information — is reflected into the optics as well.

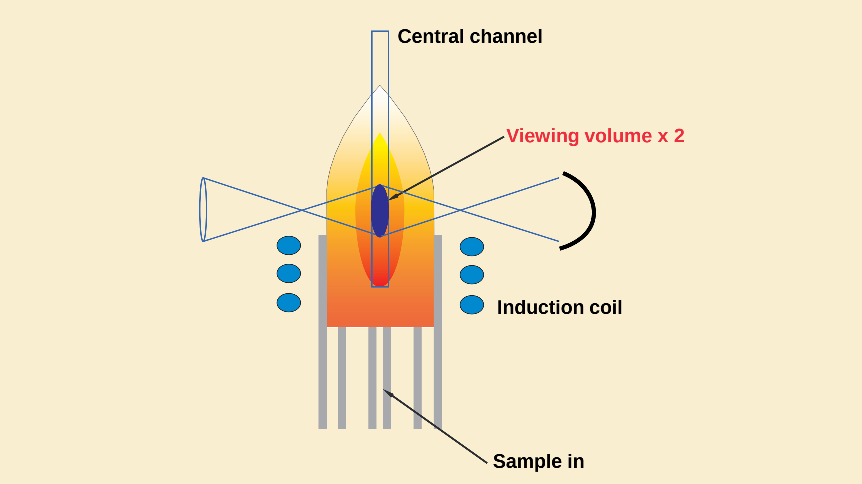
So light emitted in both directions reaches the optical system, using only a single additional reflection. Result: compared to conventional radial-view analyzers, the system's sensitivity for most elements is effectively doubled. This generally enhances the sensitivity in average by a factor of two. Alkali elements, e.g. Na and K are even enhanced by a factor of 5-10.

An analyzer using DSOI easily matches the sensitivity of vertical-torch dual-view systems. (Both can achieve about half the sensitivity of a specialized axial-view instrument.) And where these systems use periscopes with multiple reflective surfaces — each adding more light loss and thus sacrificing sensitivity — a DSOI system has only a single mirror, for minimal loss. Finally, where these other systems place an axial interface just above the ultra-hot plasma and thus can suffer higher levels of contamination and thermal stress, a DSOI system remains free of these complications.

Additionally, DSOI technology provides high stability and freedom from matrix effects, since it "blanks out" interference-prone sections of the plasma. It also provides high matrix tolerance and high linear dynamic range.

Overall, this design allows for an optimized blend of analysis speed, robustness, uptime, ease of use, and competitive operating costs. Example applications for DSOI-equipped spectrometers such as SPECTROGREEN include a wide range of routine analyses in the following fields:

- Environmental
- Consumer product safety
- Pharmaceuticals
- Chemical/Petrochemical
- Foods
- Trace element analysis in higher matrix samples



Dual Side-On Interface technology offers a single view that is effectively doubled.

CONCLUSION

Considering a new ICP-OES analyzer purchase? Make sure your spectrometer representative knows precisely what elements you expect to process for your exact application or applications.

Together, you can determine whether an axial-view, radial-view, dual-view, Multi-View, or dual side-on interface model is the best fit for your expected analytical tasks.

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