JOHN ZINK®
KOCH CHEMICAL TECHNOLOGY GROUP LIMITED

HIGH PRESSURE FLARES

INTRODUCTION

The use of flare tips operating at high pressure has become very much normal practice in petrochemical operations. The use of high pressure systems enables the operator to minimise line, vessel and relief valve sizes in order to save on capital cost and weight.

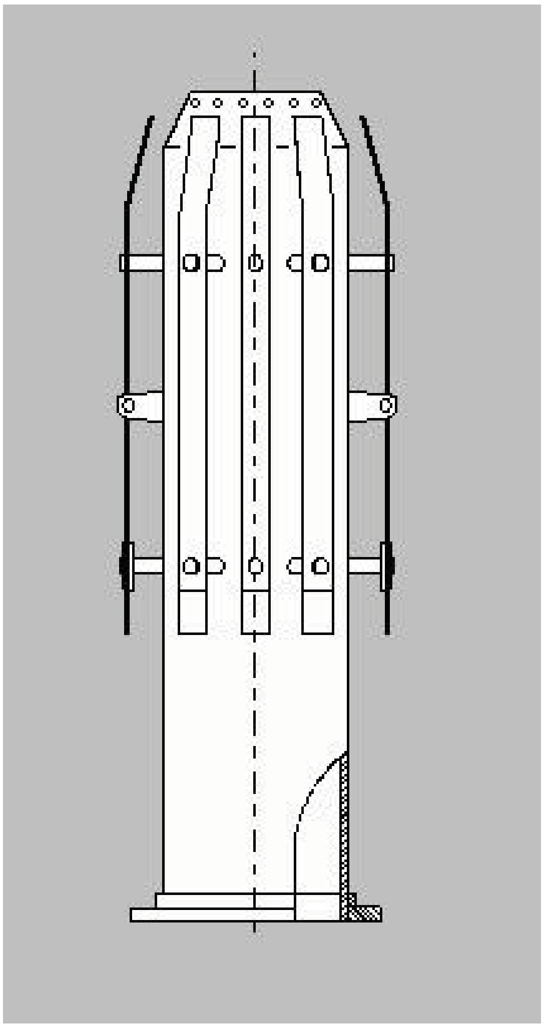
The use of a high pressure flare does not only provide advantages in terms of capital cost but also in terms of improved flare tip performance.

Typically a high pressure flare will deliver high capacity, improved efficiency, better dispersion and lower radiation. It will do this by utilising the Kinetic energy in the high pressure gas as it exits the tip, to entrain more air and create turbulence to mix that air with the flare gas. Improved aeration and mixing results in a more efficient flame which burns with a shorter and cooler flame. The result is a reduction in unburned elements in the combustion products, an increase in the proportion of entrained air allowing for improved atmospheric dispersion, and a reduction in the temperature and surface area of the flame to improve radiation levels.

The art of designing the optimum flare tip is to maximise the surface area of gas exposed to air.

John Zink and Kaldair have been the two world leaders in flare technology for a quarter of a century. The merger of the two companies in 2001 has yielded a range of flare tips and new technologies which is unique in the industry.

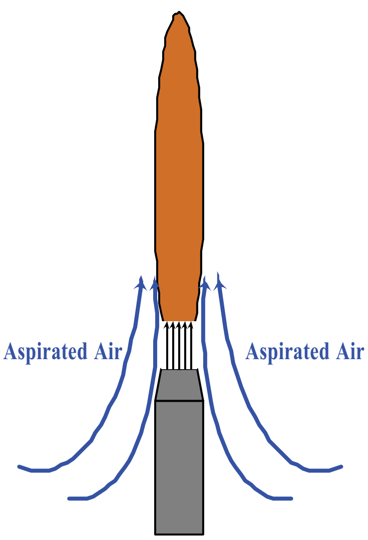
THE JOHN ZINK KSP FLARE TIP



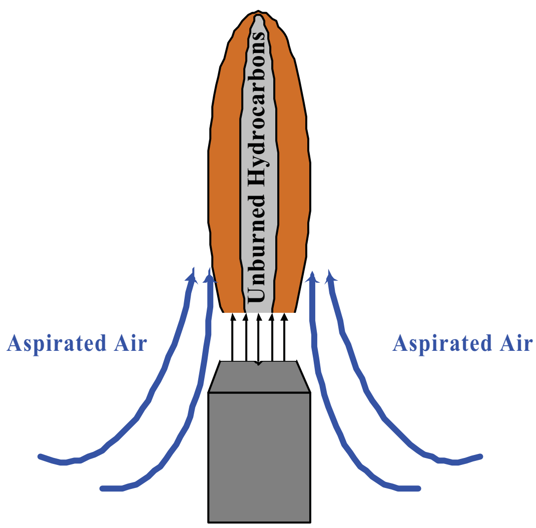
The KSP single point sonic pipeflare is the simplest form of high pressure flare tip. The KSP, originally developed by Kaldair, has been integrated into the John Zink range in its single nozzle form. The tip operates by allowing flare gas to accelerate to sonic velocity at the tip exit. For low capacity applications burning light hydrocarbon gases, this is a low cost and efficient solution for smokeless operation and reduced radiation.

Single nozzle sonic flares have limitations. This type of tip is suitable for burning light hydrocarbons smokelessly, but as the hydrocarbons become heavier then more and more smoke will result at lower flows as the kinetic energy reduces and more air is required to burn heavier hydrocarbons.

In addition there is a size limitation. As tip capacities increase then the exit diameter increases. As the flame envelop increases then it is more difficult for air to penetrate to the centre of the envelope. This results in unburned hydrocarbons at the centre of the flame ultimately producing smoke.



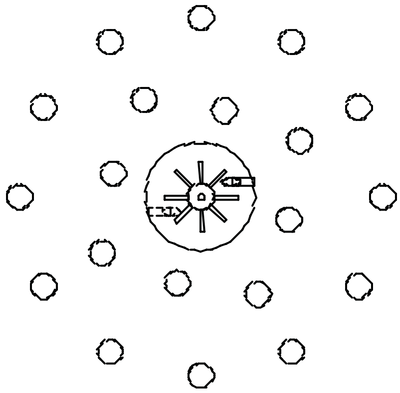
Small Diameter Nozzle



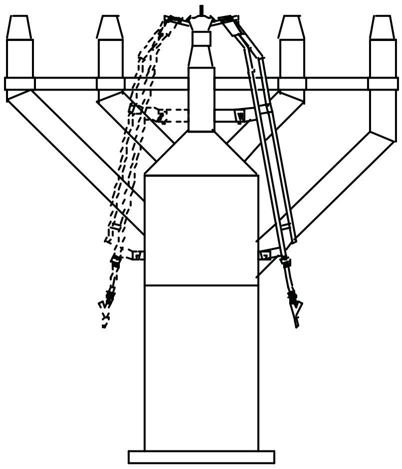
Large Diameter Nozzle

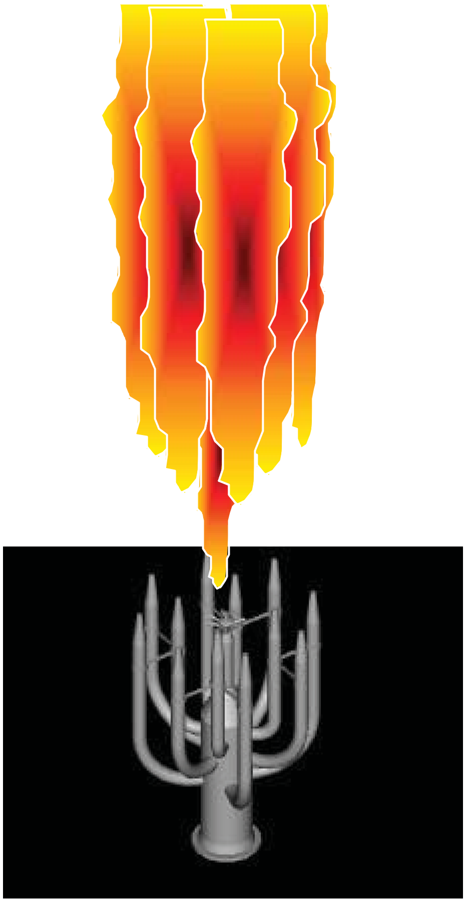
<u>**THE JOHN ZINK HYDRA FLARE TIP**</u>

To overcome the limitations of single nozzle flare tips, designers have sought to configure the tip to increase the the gas / air surface area. Designers of conventional flares have achieved this by passing the flare gas at high velocity through multiple nozzles rather than one large tip. This has the effect of increasing the surface area of gas exposed to the air and also reducing the effective diameter of the flare gas envelope allowing air to penetrate to its centre.



The highly successful John Zink Hydra flare tip operates on this principle. It is a single point flare tip with multiple sonic nozzles.





The Hydra flare tip achieves a highly aerated, stiff and stable flame inspiriting significantly more air than a conventional sonic pipeflare which in turn reduces heat radiation.

This stable flame is highly resistant to wind effects and flame pull down.

The flame is initiated above the tip metal surface contributing to extended tip life.

The Hydra is proven in service worldwide since 1989.

The phenomenon of flame lift off is common in high pressure flare tips.

The unique John Zink technology used in the Hydra flare tip incorporates a small central burner which stabilises the flame and roots it to the flare tip resulting in a tip where lift off has been eliminated.

Due to its high flame stability the Hydra tip can be operated at higher pressures than other sonic flare tips. The Hydra is recommended for flaring low to medium weight saturated hydrocarbons between 1 and 15 barg. Even at high pressures the central burner holds the flame onto the centre of the tip.

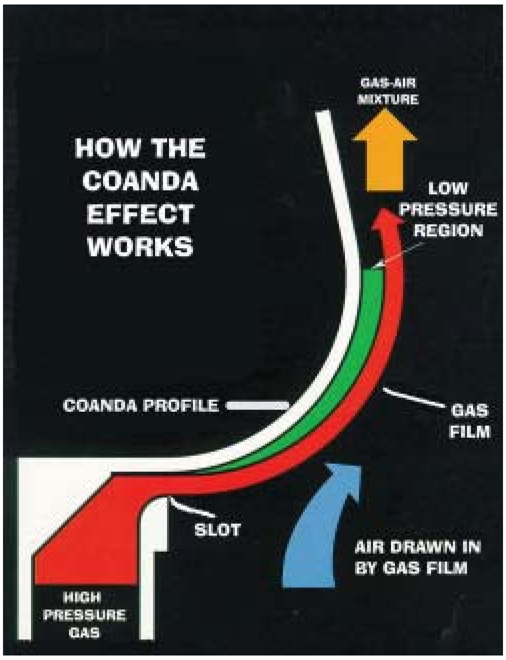
As many countries now are seeking to tax Emissions, there has been a trend in recent times to operate flare tips without pilots. This practice is not recommended by API as flare tips require pilot to remain stable. Most open pipe and multi nozzle flare tips will become unstable when operating without pilots. The central burner on the Hydra acts in place of the pilots to maintain stability.

Although this type of flare tip has superior operational characteristics over single point flare tips, it still does not provide for smokeless flaring of heavier hydrocarbon gases at low pressure low flowrates.

Coanda Technology

THE JOHN ZINK INDAIR FLARE TIP

The INDAIR flare has been developed to provide a safe and reliable high efficiency flare tip to produce a smokeless, low radiation flare design without the need for outside assist media such as forced air or steam. The INDAIR flare is a pressure-assisted flare design which utilizes the internal energy within high-pressure gas streams to produce a highly aerated, turbulent flame.



The INDAIR flare utilizes the “Coanda Effect” to entrain and mix air into the hydrocarbon gas stream. High-pressure gas is ejected radially from the annular slot at the base of the INDAIR tulip. Instead of continuing horizontally, the gas adheres to the Coanda profile and is diverted through 90 degrees, entraining up to 20 times its own volume of air in the process.

The pre-mix air/gas mixture creates very efficient, 100% smokeless combustion of the flare gases. The flame produced by this efficient pre-mixed combustion is a very low radiation, low luminance flame. The flame length is less than half of that produced by a conventional flare tip. The flame is also a thin, stiff, pencil shape that is not easily distorted by crosswinds.

Flame initiation always takes place near the maximum diameter of the tulip, insuring reliable ignition of the gas by external pilots, even on sudden venting and under high wind conditions. Smokeless, low radiative combustion is achieved without the need for ancillaries such as steam, compressed air or fuel gas.

Unlike other flare tips, the flame propagates from the outside and there is always a protective film of hydrocarbon gas insulating the Coanda tip. This avoids overheating of the flare tip and allows it to be manufactured from conventional alloy steels, using normal welding procedures, without the need for sophisticated materials such as ceramics.

Advantages and Operating Characteristics of the INDAIR Flare

High Pressure Operation	Since the INDAIR flare operates at elevated pressure when burning HP gas (rather than near atmospheric pressure as with a conventional flare), significant savings in header size and knock-out vessel size may be made. The primary design consideration in sizing relief headers and liquid knockout vessels is the velocity of the gas. Maintaining a high backpressure at the flare tip keeps the gas compressed in the upstream flare header. This reduces the velocity of the gas for a given relief flow rate of gas.
Efficient Air Entrainment and Mixing	The efficiency of any combustion process is largely a function of the efficiency of the fuel/air mixing. Conventional low-pressure pipeflares emit a cylinder of hydrocarbon gases that rely totally on natural diffusion of air into the flame. This produces relatively low combustion efficiency. Multi-point sonic pipeflare tip designs improve the efficiency by splitting the flow between smaller, separated cylinders of hydrocarbon gases and creating some air entrainment into the flame due to the sonic jet nozzles which are used. The unique INDAIR flare tip, based on the Coanda Effect, forms a thin film of hydrocarbon which entrains and pre-mixes air prior to combustion. The INDAIR flare, in most cases, produces combustion efficiencies in excess of 99.9%.

Smokeless Operation	INDAIR flares will provide smokeless combustion of high-pressure gas over their specified operating range. Conventional multi-point sonic flare tip designs can produce smoke when flaring heavy hydrocarbon gases, unsaturated hydrocarbon gases, or gas streams containing liquid droplets. The INDAIR flare tip, due to its unique pre-mixed turbulent flame, high air entrainment rate, and thin film combustion technique, will produce smokeless flaring of any hydrocarbon gas stream.
Low Radiation	The INDAIR flare produces a highly aerated turbulent diffusion flame that radiates far less heat than the equivalent flame produced by the conventional pipeflare. The reduction in radiation is achieved without the use of ancillaries such as steam, compressed air or fuel gas. The Fraction of Heat Radiated (F), which is also often termed flame Emissivity (e), is the portion of a flame's gross heat release that is emitted as radiation from the flame. The F-factor (or Emissivity) of INDAIR flares has been measured for a wide range of operating conditions. The value of F for INDAIR flares varies from 0.08 to 0.10. A value for F of 0.20 to 0.25 is used for an API-type pipe flare. A value for F of 0.12 to 0.15 is produced by conventional multi-point sonic flare tip designs.
Flame Length	The turbulent INDAIR diffusion flame with its increased combustion intensity is far shorter than that of an equivalent conventional flare. The flame length produced by an INDAIR flare is less than half that produced by a conventional API-type pipeflare
Flame Stability	In contrast to the wind sensitive flame produced by a conventional flare, the INDAIR flare produces a flame with a high directional stability which is not easily distorted by cross-winds. The flame is extremely stable; in fact, INDAIR flares have been operating successfully in the North Sea in wind speeds in excess of 100 mph.
Liquid Carry-Over	Even with the best run production/separation installations, liquid carry-over to the flare line can take place. With conventional pipeflares or multi-point sonic flare tips this can be a serious potential hazard giving rise to 'flaming rain' falling and pollution affecting a wide area. The intense shear in the INDAIR slot region ensures efficient atomization of liquids, aiding vaporization and combustion. The INDAIR flare is capable of burning 25% by weight of liquid carry-over without any fall-out or smoke production whatsoever. The INDAIR flare tip can effectively atomize liquid particles with size in excess of 1200 microns. This feature means that, in many cases, the flare may be operated without a liquid knockout drum in the HP flare line.

Stiff Directional Flame

The unique geometry and stiff directional flame allow the Indair to be mounted at an angle without any detrimental effect on the tip operation or life. This feature is particularly useful in offshore application where the flame can be angled away from the platform or FPSO in order to reduce radiation on deck.

Unique Metallurgical Design

Extensive research and development has led to recent advances in the metallurgical design of INDAIR flare tips. Flaring is a unique high temperature service in that the metal is often exposed to extreme temperature differentials across the periphery of the flare tip, thermal shock during a sudden blowdown condition, and very high temperatures during low to moderate flow rates. Conventional high nickel alloys used in many flare designs can withstand very high temperatures, but can be subject to cracking and failure when exposed to repeated cycles of thermal shock and high temperature differentials.

The INDAIR flare tip uses a special high-nickel alloy that combines high temperature strength and high ductility. All of the metal surfaces that have contact with the flame (i.e. the entire “tulip” assembly) are fabricated with this alloy. This unique design enables the INDAIR flare to easily withstand a vast array of harsh operating conditions. The unique INDAIR flare tip design can provide long, maintenance-free service life.

Reliable Ignition

The INDAIR flame always initiates near the maximum tip diameter so that reliable ignition of the INDAIR flame is achieved, even on sudden venting and under high wind conditions.

Flare Capacities

In general, the volumetric gas flow rate (Q) through a sonic flare tip is a function of the absolute gas pressure (P) at the exit area (A) and the specific gravity and absolute temperature of the gas (Sg, T). The multiplier K is a function of flare design and to a lesser extent gas composition.

$$Q = KPA (T \times Sg)-0.5$$

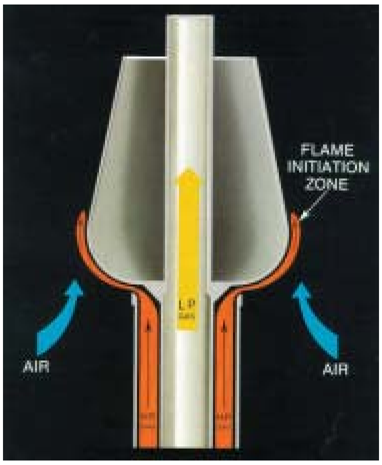
For conventional sonic flare tips, the outlet area A is fixed, and turndown is largely governed by the ratio of operating pressures:

$$\text{Turndown} = P \text{ available} / P \text{ minimum}$$

Where P minimum is normally around 10 psig.

With the unique variable slot (VS) INDAIR design, the area varies linearly with pressure. Much larger turndown ratios can be achieved since:

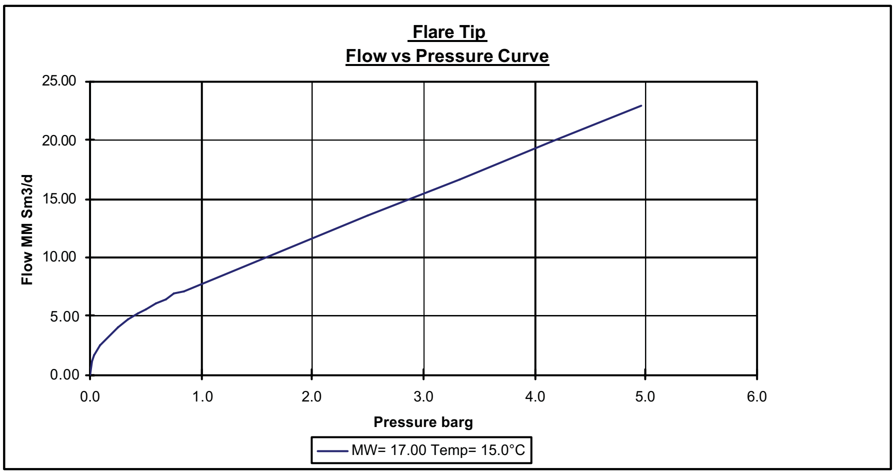
$$\text{Turndown} = (P \text{ available} \times A \text{ max}) / (P \text{ min} \times A \text{ min})$$



THE FIXED SLOT INDAIR

Few other devices in engineering are required to perform satisfactorily over such a wide range of operation as the flare tip. It must be able to handle all flow conditions from purge to full relief. This it can do but it is fair to say that it handles some conditions better than others. Essentially at high flow the flame is more controlled and burns away from the flare tip. Under this condition metal temperatures are low and the tip would last an almost indefinite period. However under low flow conditions flame control is lost. It burns around the tip or even inside it, metal temperatures are high and cyclical. This is the situation that burns out flare tips and unfortunately it is the one commonly encountered on modern platforms that export or re-inject their gas. The fixed slot version of the Indair is most susceptible to damage due to continued operation at low pressures and therefore should only be considered where high flows are anticipated or where continuous purging is with nitrogen.. The tip is recommended for venting applications where high air entrainment and dilution are required to aid dispersion.

It is a physical fact that the shape of the flow/pressure curve of an orifice discharging to atmosphere is such that relatively high flows are achieved at low upstream pressures i.e. if an orifice were designed to pass 23 MMSM³/D at 5 barg then it would still pass 2.8 MMSM³/D at only 0.1 barg. In flaring terms this latter pressure is not enough to produce a turbulent, stiff flame and the result is a laminar diffusion flame (like a pipeflare). The region that a Coanda flare will give good performance starts at about 0.2 barg is fully developed by 0.8 barg and carries on to 5 barg or above.



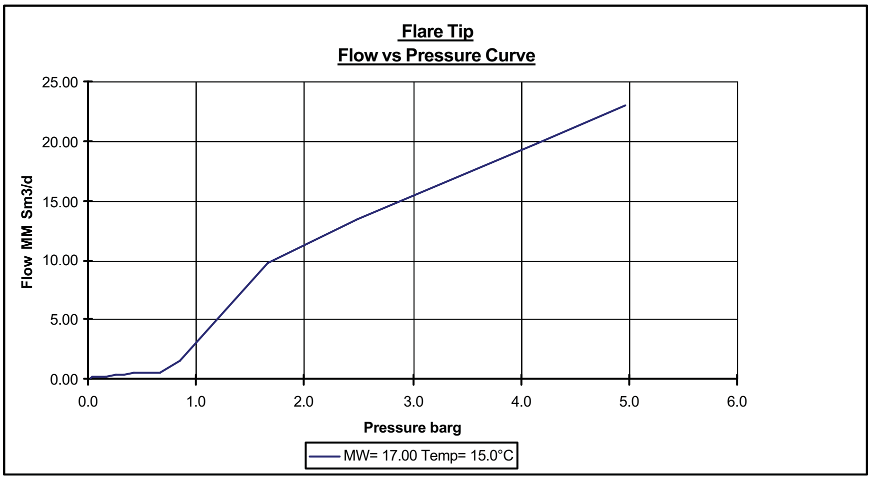
So, in the case of our 23 MMSM³/D flare, this will give it's best performance from 6.5 to 23 MMSM³/D, give improving performance from 2.8 to 6.5 MMSM³/D and pipeflare like flames below 2.8 MMSM³/D. Thus in the area where it's performance is worst is just where it will operate most of the time.

HL Indair

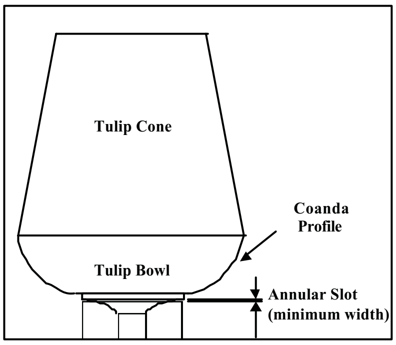
A variant of the Indair is the HL which allows a separate LP case to be passed through the centre of the Indair Tulip. The efficiency of the Indair in entraining air is such that when HP and LP are firing simultaneously there is enough air entrained to allow both LP and HP streams to operate smokelessly.

VARIABLE SLOT INDAIR

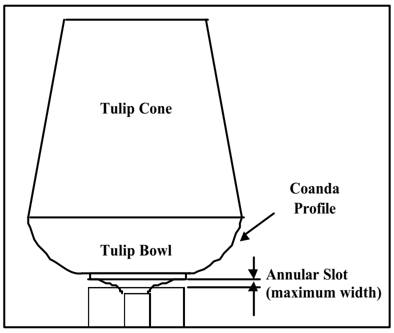
The only solution for providing reasonable smokeless turndown with a conventional sonic flare tip is to provide an elaborate multi-flare tip design with many flare stages separated by control valves. This type of design is therefore very expensive to install and maintain



There is another way to "stage" a flare, that is to say to modify it's flow/pressure curve so that it operates at higher pressures at lower flows. This can only be done by varying the discharge flow area of the flare tip itself. The INDAIR flare lends itself to this very well. It is apparent that the gas slot area can be changed by raising or lowering the tulip assembly within the flare tip body.



The whole tulip and inner stack is allowed to move up and down in response to applied flare gas pressure. In effect we have a force balance with the tulip weight, Coanda thrust and spring force all acting downwards being opposed by the upward force caused by the internal gas pressure. The rating of the springs determines the opening characteristic which is normally to start opening at 0.7 barg and be fully open by 2.0 barg



The slot width (which determines the tip outlet area) remains at a small size during low gas flow rates and increases proportional with increase in gas flow. This design provides near infinite smokeless turndown design while maintaining high maximum flow capacities. This variable slot INDAIR design, therefore, produces 100% smokeless flaring from minimum (purge) to maximum design flow rates.

The unique variable slot INDAIR flare tip provides infinite smokeless turndown without the need for these elaborate staged multi-flare designs. A single INDAIR flare tip provides 100% smokeless flaring and high flaring capacity with a very low radiation flame.

The spring-loaded mechanism is extremely reliable, with a design similar to that used in safety relief valves.

THE JOHN ZINK KMI FLARE TIP

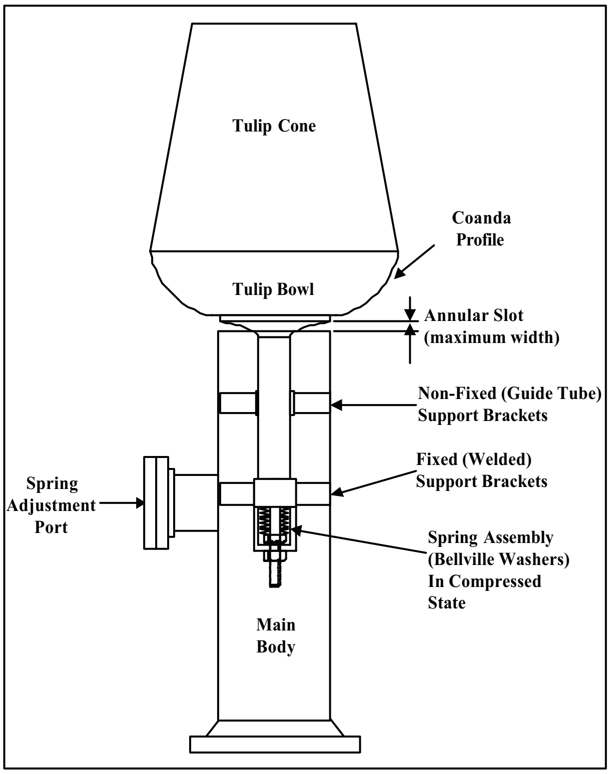
The KMI is a Hybrid of the Hydra and Indair Variable slot technology. The concept of multiple Indair tips being located in an array has been used for many years however John Zink have developed a multi-nozzle flare tip which is a single point tip with multiple Indair Nozzles. This not only has provided the multi-arm advantages of the Hydra, increasing the flare gas surface area exposed to the air, but also employs the infinite turndown features of the Variable Slot Indair. In addition the turndown flexibility can be enhanced further by varying the spring rates on the individual nozzles such that the flare tip can act as a staged system in itself. Thus the tip can be set up to bring nozzles online in turn such that at low flows only one or two nozzles will have their slots open while all the others are closed. As the pressure and flow increase then slots can open in sequence until at full flow all slots are fully open.

KMI Advantages

The KMI benefits from all of the advantages of single tulip Indair's described above, but also has some key advantages:

- The large Indair tulips are a two part construction with a pressed bowl and a fabricated cone. These parts are welded together. In operation this construction does have an inherent weakness in the welds which over time can reduce the life of the tip. The small Indair tulips used in the KMI are investment cast single part construction and very robust. The ratio of bowl diameter to wall thickness is much higher for the smaller tulip and therefore the tulip is extremely stable.

- As the KMI tulips are very small they are easily man handled. Therefore in the event that any tulips require changing, it can be done without the use of crane a crane. In addition the replacement of an investment cast small tulip is not expensive where the manufacturing cost of a large tulip is relatively high.



- The KMI design allows much more flexibility than the single point tip. The springs on the KMI can be set at different ratios to allow slots on some arms to open earlier than slots on others. This can be used to effectively stage the flare. In this way at low flows it is possible to operate with one 1 or 2 slots open thus optimizing the pressures and saving wear and tear on other nozzles.

- The spring system is maintenance free and will give many years of trouble free operation. Often there are concerns over the possibility of the springs failing and the tip not opening. The mechanism has a fail safe, i.e. fail open, arrangement. Our experience has been that we have not, in 30 years of supplying Indair's, had a report of a spring failure with tips operating within their design criteria.

- Over a 20 year flare life all types of flare tip will require a certain extent of refurbishment. For the single point Indair tip this would mean a new tulip on average every 5 to 7 years. For the multipoint we would expect this period to be much longer and only a few of the tulips may need changing if at all. Maintenance costs and down time will be reduced.

The Variable Slot Indair has been installed in over 300 installations worldwide for nearly 30 years.

With smokeless flaring being a more important design feature in recent years the variable slot INDAIR has become the choice of most major oil and gas producers.