Mr. Jim Raba

U.S. Department of Energy Building Technologies Program, Mailstop EE-5B
1000 Independence Avenue, SW Washington, D.C. 20585-0121

Subject: Docket # EERE-2014-BT-STD-0051, and/or RIN 1904-AD40
Meeting 24th February 2015

Dear Mr Raba,

Thanks for the invitation to discuss and explain comments to a new proposed gas compressor efficiency standard. The attached comments reflect our recent discussion and you recent clarification questions in Washington DC and our in addition to our January submission

Regards,

Christean Kapp

Sr VP HOERBIGER KT Compression Solutions Segment

Item 4-2: *DOE requests comment about whether the test procedures in ISO 1217:2009 and ISO 5389:2005, which address the testing of displacement and turbo compressors, respectively, would be appropriate for rating gas compressors. DOE also requests information about other applicable test procedures it should consider along with any deficiencies or issues that should be addressed prior to prescribing test procedure requirements to measure energy consumption.*

We would suggest to define a standard to measure efficiency of recip compressors in situ.

DOE Question 1. *Suggestion that a testing standard to measure reciprocating compressor efficiency in situ – i.e. on-site. Hoerbiger, at 3. Does this mean that a testing/standards approach that measures reciprocator efficiency as a separate, independent component would not be workable? (If it doesn't mean that, how could a component-based (i.e. reciprocating compressor tested separately away from its field implementation site) work?)*

HOERBIGER believes that site testing is a viable option for comparing alternate technologies, reciprocating compressor and package designs. In situ testing is complicated when comparing a guaranteed power requirement with an actual measured power consumption where changing field conditions and actual compressor station design may have significant impact on performance that is difficult to differentiate from the actual compressor performance. The effort to eliminate this "noise" from actual performance can be quite high.

Item 5-1: *DOE is seeking both present and historical shipments data (specifically from 2003- 2013) for gas compressors, with further breakdowns, where available, including, but not limited to, equipment type (both compression principle and driver type), equipment size, and application. DOE is also interested in comments regarding how gas compressors are manufactured and shipped as original equipment from the manufacturer, for example, as a package (i.e., with both compressor and prime mover), or as a separate component, or both*.

Shipments and Values The number of compressor installed and being shipped in the presentation is in our opinion far too conservative.

DOE Question 2. *Shipments and Values. Hoerbiger at 4. By how large a magnitude are DOE's estimated installation and shipment estimates too small? ("Many thousands.") And (to clarify) are the claimed estimates from Hoerbiger based on U.S.-only or global numbers?*

The installed base for reciprocating compressors in the USA for oil & gas applications is probably underestimated by a factor of 2 according to HOERBIGER own view.

Shipments of new reciprocating compressors for the same market are underestimated by a factor of app 20 as the number of compressors installed in projects within a state not requiring federal approval are considerably higher than involved in inner state projects.

HOERBIGER with its own shipments to compressor OEMs can easily see much higher numbers of reciprocating compressors being shipped and operating in the field than the EPA or DOE has tabularized. We however feel we cannot pass on that information without breaching confidentiality with our compressor OEM customers.

The Gas Compressor Association (GCA) with participation of major OEMs has reciprocating compressor numbers far in excess of known to the EPA. These are partially market segmented and by regions too. The numbers are actually conservative as not all small or large OEMs report into the GCA. It is fair to say there are many thousands of reciprocating compressors going into O&G every year. The International Compressed Air & Allied Machinery Committee (ICAAMC) provides centrifugal compressor numbers split by application, driver type and geography too. I suggest the DOE should reach out to these organizations.

Item 5-2: *DOE requests shipment information on upstream and gathering natural gas compressors, and how their numbers compare to those of natural gas compressors in other applications*

As mentioned before the numbers of upstream and gathering gas compressors in our opinion far outnumber those of any midstream or downstream application. They are however far smaller with typical horsepower ranges 75 to ca.1,200 HP.

DOE Question 3. *Upstream and Gathering vs. Other Applications. Hoerbiger at 4. Are the estimates claimed by Hoerbiger based on U.S.-only numbers? Magnitude of the difference between DOE's estimates and "actual" numbers?*

Yes, we had assumed US numbers only, Whilst not exact to the last compressor we believe our view is more accurate than DOE or EPA.

Item 5-3: *DOE seeks comment on how an energy conservation standard for gas compressors might impact future equipment shipments***.**

HOERBIGER believes it is possible to measurably improve reciprocating compressor efficiencies at the design point by using premium efficiency compressor valves vs industrial std. that may impact the cost of a typical compressor package only marginally. This should have a minimal impact on compressor demand and shipments.

DOE Question 4. *Claim that reciprocating compressor efficiency can be improved by using "premium efficiency compressor valves" vs. standard valve designs for a "marginally" higher cost. "This should have a minimal impact on compressor demand and shipments." Hoerbiger, at 5. Estimated cost increase – i.e. extent of this cost impact? (Would need to clarify whether this projected increase would account for expected price mark-ups.)*

Going through the value chain and assuming a small 200 HP gas gathering compressor we can estimate that if premium valves cost 25% (assumed number for evaluation purposes only) more than standard valves from HOERBIGER to an OEM, the OEMs total bare compressor price might change by 1-2% and a packagers price to the End User may increase below 1%. The aftermarket increase to the end user would be larger by about 25% higher depending on the markups by OEMs and service providers. The numbers are typical and may vary by size and complexity of the compressor.

DOE Question 5. *Valve improvement. Hoerbiger at 5. What is the fundamental difference between a more efficient valve and a more common standard valve? Any utility differences or drawbacks?*

The fundamental difference between a premium and standard valve are the improved highly efficient and larger flow passages and the more durable materials and design of the crucial valve plate that provides the opening and closing motion for the reciprocating compressor.

A proven high efficiency design for a specific application has no drawbacks in terms of reliability or any unusual utility demands

Proven control technologies are available that improve part load efficiencies dramatically but may have a noticeable impact on the cost of a compressor package. HOERBIGER suggests that these reverse flow suction unloader control technologies may only technically available for slow and medium speed compressors (<1,200 rpm).

There are many other factors that influence compressor efficiency, such as interstage cooler and pulsation damper pressure losses, pulsation itself, sizing and specific designs of cylinders etc. which can be discussed elsewhere.

Item 5-7: *DOE requests comment on the degree of gas compressor oversizing that is prevalent under current industry practices. Specifically, the degree to which this oversizing may be a factor for different end-use applications.*

Oversizing of compressors is common in the industry and to some degree necessary. API 618 and API 617 typically call out for the driver to be sized at least 10% larger than the highest power requirement of the compressor. This is done to cope with manufacturing tolerances of the compressor as well as measurement and definition issues.

DOE Question 6. *API 618 and 617. Hoerbiger at 6. Do these two API documents set out mandatory specifications/procedures that the petroleum/natural gas industry requires all compressor manufacturers to meet? (Which do they set out – specs, procs, or both?) Are they "best practices" or are they guidelines? How are these documents used by compressor manufacturers? (Or are they intended mainly for use by pipeline operators to ensure that they have a checklist of best practices?)*

The American Petroleum Institute Standards have been in use for decades and are updated roughly every 5-10 years to keep up with technology development experience. These standards describe basically best practice on how to specify, design, test and build a compressor. Whilst not meant specifically to describe efficiency, safety and reliability many aspects do touch upon these. US Oil companies nationally and international use these standards upon which they overlay their own company and project specifications. International Oil and gas companies do likewise. US Natural Gas companies for the most part do NOT use API specifications.

Compressors in the oil and gas industry run at numerous operating points. In many cases real life operating conditions, especially upstream and midstream could not have been foreseen accurately and the operator and the OEM need to provide some oversizing to cope with this. Mole weights , flow rates, pressures , temperatures , gas mixes may be different at onset than expected and may well change over time as well, sometimes dramatically. Lease compressors must be suitable for a wide range of conditions as every well site will have different conditions. Flexibility is often key.

The typical shale gas well flow rate can be sure to drop off quickly after well completion, so compressor oversizing is inevitable. Many operators will not have the ability to accommodate this drop, and bypassing of the gas back to suction is common. This results in drastic energy losses. There are capacity products offered to better accommodate this, but are seldom utilized to the fullest either with new units or retrofits in the field.

Compressor Drive Turbines & Engines need to be oversized and are sometimes de-rated depending on the ambient conditions, i.e. altitude, atmospheric pressure & day and night time temperatures. As these drivers come only in certain incremental sizes an oversizing of the compressor train beyond 10% to the design point and much higher to part load operating points may be inevitable.

Item 5-8: *Are gas compressors marketed and sold on the basis of efficiency? Do certain customers tend to purchase certain compressor types or efficiency levels? What makes compressors more or less efficient?*

It isn't possible to make a generalized statement. We see that some End Users prefer efficiency over capital costs and vice versa. Very often other factors such as aftermarket and technical support, harmonization to existing fleet, reliability, availability, operator familiarity with specific equipment etc. are very important too.

DOE Question 7. End User Preferences. Hoerbiger at 7. Which end users, based on Hoerbiger's experience, tend to place a higher emphasis on equipment efficiency?

There is at times a preference to use screw over reciprocating or reciprocating over centrifugal compressors. There may be preferences to use different types of drivers like e-motors, engines or gas turbines. We see very often that emotors and engines drive reciprocating compressors but turbo compressors tend to be driven by emotors and turbines (not by recip engines) However more often it is a custom choice depending on the project objective to be achieved.

The efficiency of a reciprocating compressor amongst other factors can be influenced by:

- cylinder sizing
- cooler pressure losses
- pulsation control and pressure losses
- process piping layout
- valve type and size
- control system for part load operation

DOE Question 8. *Reciprocating Compressor Efficiency. Hoerbiger at 7. Regarding the various factors listed, what would be the proportional impacts (re: energy efficiency) of each? What would be the relative costs – from highest to lowest?*

Very difficult to quantify in a number but a relative ranking could be established like this:

COSTS:

High relative costs:	cylinder sizing, process piping layout, control system part load
Medium	cooler pressure losses, pulsation control
Low	valve type and size

BENEFITS:

High relative benefits:	process piping layout, control system part load
Medium	cylinder sizing, process piping layout, valve type and size

Centrifugal compressors may be impacted by:

- cooler pressure losses
- configuration, (speed, number and type of impellers)
- type of controls (var. speed, suction, discharge throttling etc.)

DOE Question 9. *Centrifugal Compressor Efficiency. Hoerbiger at 7. Regarding the various factors listed, what would be the proportional impacts (re: energy efficiency) of each? What would be the relative costs – from highest to lowest?*

COSTS:
High relative costs: variable speed control, configuration (no. of impellers)
Medium speed of compressor, type of impellers
Low suction, discharge throttling

BENEFITS:
High relative benefits: variable speed control
Medium type of impeller, no. of impellers (depends on case)
Low suction and discharge throttling

Item 5-9*: DOE seeks information on any voluntary efforts by manufacturers that are already in place to improve the energy efficiency of gas compressors and what type of voluntary efforts to improve efficiency, if any, are likely to occur in the near future.*

Whilst we see some compressor OEMs work on more efficient compressors, this isn't an industry wide trend and we will let those OEMs report on their efforts as they wish to.

HORBIGER has had a strong focus on more efficient compressor valves over decades and, newer, more efficient designs are being used by selected reciprocating compressor OEMs. These newer types of valves have a measurable impact on efficiency. In particular ring valves and profiled plate valves are now entering the main stream markets. Improved materials and designs are being field tested as we speak.

DOE Question 10. *Improved Compressor Efficiency. Hoerbiger at 8. What is the motivation for Hoerbiger to improve compressor efficiency? (Why make the initial investment in the first instance if the rest of the market sees it as too costly?)*

HOERBIGER serves a global market for compression and several markets stand out where compressor efficiency is very important, this includes European and Asian refineries and even European natural gas compressor operators as well as air separation companies. We do a lot of business there and wish to provide US operators with the choice to use the same technology.

Item 5-13*: DOE seeks comment of what consumer populations would be disproportionately affected if DOE were to adopt new energy conservation standards.*

The impact would naturally depend on what specific energy conservation measures would be adopted.

DOE Question 11. *Impact Projections. Hoerbiger at 9. How would the projections compare between an on-site approach and component-based approach? (Orders of magnitude?)*

This depends greatly. Energy benefits based on improved valve technology may not be as obvious on very small compressors as it is on medium and larger size ones.

Item 6-4: *DOE seeks input on technologies available to reduce gas leakage, including the cost effectiveness and applicability of each.*

HOERBIGER have excellent experience with our balance capped design (BCD) packing rings which drive down emissions considerably while extending life at low emissions. These packing rings are somewhat more expensive than traditional R/T rings but the impact is negligible when seen in terms of overall compressor cost. A new system is coming on board that will provide effectively zero emissions from a recip compressor. It is more efficient in reducing gas leakage in all operating or stand still conditions but it comes with a higher commercial impact than the BCDs.

DOE Question 12. *Balance Capped Design Packing Rings. Hoerbiger at 11. What is the cost differential between "traditional R/T rings" and BCD rings? ("[N]egligible when seen in terms of overall compressor cost." But on a component-basis – cost differential? (NOTE to self – Are percentages useless here if we're talking about pennies per ring?)*

A BCD ring may order of magnitude be 20% or so higher in cost than a traditional radial tangent ring, as a ring may only cost a 50-250$, the absolute impact is quite limited even when you need 5 or so of these per cylinder. We have enough data from actual end users to suggest the BCD run at least twice as long than R/Ts and are therefore cheaper to operate than conventional packing when considering replacement costs.

Item 6-5: *DOE requests specific comment on compressor blowdown, including estimated leak volume, technologies able to reduce blowdown frequency and capture the gas blown down.*

Compressor blowdown is primarily an operational issue not necessarily a reciprocating compressor design question. A reciprocating compressor will leak dramatically in stand still conditions until pipe process pressure is let out sufficiently. How long that takes is dependent on the actual compressor, process plant and gas pipework etc. In some instances blowdown may be associated with the capability of a driver to start a compressor, generally the higher the pressure the larger a driver has to be sized.

Many sites have yard gate or ball valves that continue to leak whilst the unit is down for maintenance or when the unit is in standby. This pressured leaking gas source is due to the inherent design of compressor rod packing seals, which require a moving rod to effectively seal off. For obvious safety reasons the blowdown valves therefore must remain open letting hundreds of cubic feet of gas escape per cylinder

Zero emissions sealing systems (in testing stage at Hoerbiger) or leaked gas recovery systems are the only ways to prevent this emissions source.

DOE Question 13. *Blowdown. Hoerbiger at 11. Leaks, etc. cited as areas of potential concern – occur even while the system is in standby mode. Does this mean that a component-based approach would be significantly less effective than an on-site approach? Or are there still significant opportunities for improved efficiency by tackling current limitations at the component-level?*

This is the big question that the EPA and research institutes are still grappling with. Blow downs do create a huge amount of greenhouse gas emissions (incl some VOCs) when they do occur intermittently

The EPA describes in **52738 Federal Register** / Vol. 76, No. 163 / Tuesday, August 23, 2011 / Proposed Rules leakages in well working, worn and standstill conditions

As such however a recip compressor constantly leaks regularly a large amount of greenhouse compared to well maintained valves and tanks, especially when the compressors are pressurized but shut down.

Item 6-7: *DOE seeks recommendations on sources of data, or analysis methods that would provide demand profiles for gas compressors and their end-use applications. Further, DOE seeks comment on what gas compressor design features would affect their typical demand profile.*

Demand profiles typically would have to come from End Users or in some instances process licensors (common only in refinery and chemical). HOERBIGER cannot pass on information already in our possession due to confidentiality concerns. What we can observe is that demand profiles can be very individual, i.e. one gas storage compressor will have a different profile than the next one, even though they can be both characterized as variable pressure ratios and flows at a moderate and high pressure levels.

DOE Question 14. *Demand Profiles. Hoerbiger at 12. If DOE adopted a system-based approach, would a default demand profile be sufficient for drawing comparisons among different compressors. If not, and DOE uses a component-based approach, would these demand profiles still be relevant? (If so, how?) With respect to end-user demand profiles, do these include the "extra performance" that an end user may want/need? Is there a standard margin of additional performance that end-users typically seek from their compressors?*

I would suggest that a standard demand profile is very, very difficult to define to do justice to the problem. Conditions do change from site to site and different operators have different demands. It is probably true that an oil and gas compressor never truly operates at the factory specified conditions

However when an End User purchases a custom designed oil and gas compressor he specifies to the OEM the operating conditions he is considering and this could be the basis of demand profile that should be evaluated, even if operations later turn out to be different

There are lease compressors, especially upstream where by the very nature actual conditions change as they are moved around from site to site.

Item 6-9*: DOE seeks comment on the types, and rate of adoption, of different control systems that are employed to adjust a gas compressor's output to meet end-use application demands during off-design operation.*

There are several different controls systems available for reciprocating compressors:

A) Suction or discharge pressure throttling is energetically particularly wasteful but cost effective to install.

B) Recycle or Flow Back operation which entails the use of a recycle valve external to the compressor is also energetically wasteful as the entire flow is compressed and part of the flow is recycled to be re-compressed again.

C) Speed control. Most engines are limited in this capability for combustions emissions or rotor dynamic reasons. emotors drives can be modified to accept variable frequency controls but this is a capital intensive, complex solution that also is still typically limited to 50-70% minimum speeds. If required to operate below these speed the compressor may operate very inefficiently.

***DOE Question: 15**. Speed Control. Hoerbiger at 13-14. What applications are most likely to be appropriate for electric motor-based solutions? (Limitations pointed out in the comments – if limited in these ways, are electric motor-based drivers effectively a non-option?) What is the cost differential between an electric motor-driven compressor and compressors driven by other means (e.g. engine, turbine-driven, others)?*

Many operators are "forced" to go electric when they step through the different state and federal air permitting regulations., the availability of nearby high voltage electricity is another major concern, if one has to bring in several miles of transmission lines it may not be economically feasible.

There are many different publications on cost effectiveness on turbine vs motor drives with differing results. Generally motor drives are capital cost effective, but many believe they have high "fuel" costs. Turbines have high maintenance costs for hot section repairs. Engines have higher efficiencies than turbines, are cheaper and require less maintenance but they are size limited compared to gas turbines. Every project may come to a slightly different conclusion as to what is the best fit for the actual project in hand, one size does not fit all.

M.J. Melfi, "Quantifying the energy efficiency of motors fed by adjustable frequency inverters," IEEE 56th annual Industrial Applications Society Petroleum and Chemical Industry conference, 2009, ISBN: 978-1-4244-3798-6. Describes the efficiency behavior or motors and variable frequency drives by load and speed

D) Fixed and variable clearance pockets are popular and available for reciprocating compressors, the vast majorities are manually operated but there are a few models that are hydraulically or electrically operated. When used as designed they are effective in improving compressor efficiencies at part load. However manual pockets may not be able to react fast enough as operator intervention is required and therefore may be at times inefficient.

E) Step-wise unloaders include finger unloaders and pocket valves which reduce horsepower and capacity in discrete steps. These are operated by pneumatic actuators and are relatively easy to automate. The down side is that the compressor may have to load and unload periodically around particular set points and they because of their operation in discrete steps can reduce but not minimize power losses.

F) Step-less Reverse Flow Suction Unloaders are available and proven to reduce horsepower demands on medium and large size compressors operating in part load, and can operate at any specific set point between 20-100% load and are inherently very stable.

Item 6-11*: DOE seeks comment about how gas compressor efficiency is likely to change over time in the absence of standards.*

If past performance is assumed to be typical of the future reciprocating compressor efficiency improvements will be slow at best in most application areas.

Main driver will be if fuel savings are going to be significant or not. With natural gas as a popular fuel at record low pricing and expecting to be at low levels for quite a few years to come there may be little incentive for the End User to improve compressor efficiencies or operate more efficiently in the United States. However electrically driven compressors in the current environment are much more expensive to operate than engine or turbine driven compressors.

DOE Question 16. *Compressor Efficiency. Hoerbiger at 15. What "encouragement" for end-users to adopt a "best solution" re: efficiency would Hoerbiger suggest that DOE consider? In the alternative, are there certain types of design elements that would help ensure the adoption of more efficient (and better operating?) compressors?*

In my opinion best practice is to determine life cycle costing. Some operators do this, most don't do this well in the US.

Life Cycle costing consists of CAPEX (Capital expenditure), anticipated regular, recommended MAINTEX (maintenance cost) and OPEX (operating or "fuel") over a certain time period.

API 617/618 specify a twenty year life of a compressor, this may be an appropriate period to conduct a life cycle cost evaluation

Operators who do a version of this are Air Separation companies who specify in their procurement specifications that a turbo compressor CAPEX will be evaluated together with its OPEX (i.e.5000$/KW per operating point) . MAINTEX is partially lumped into CAPEX as the end user will purchase all critical spare parts for 2 years with the new compressor

Many Multi National and National Oil companies do sophisticated 20 year life cycle evaluations. Often the criteria are transparent in the inquiry documents so that the OEM can provide their optimized solution in the initial bid. The actual fuel or energy costs per unit are specified by the purchaser.

Item 6-18*: DOE seeks* recommendations on sources *of data or analysis methods correlating gas compressor maintenance and repair with gas compressor lifetime and efficiency.*

This would be something a user of reciprocating compressors should answer and provide.

DOE Question 17. *Maintenance Costs. Hoerbiger at 16. What would be the additional maintenance efforts/costs that would be involved with using a more efficient compressor? Same question in the context of potential repair work/costs.*

In most instances maintenance efforts may not be much higher for efficient equipment, 3-D impellers do not require more maintenance, however when they are replaced it will cost a little more than 2-D impellers