Technical Overview No. GTB 44602

Grayloc® Clamp Connectors vs. Conventional Flanges

Steve Klak, P.E. – Vice President Engineering

A. Grayloc Clamp Connectors vs. Flanges

Grayloc clamp connectors outperform conventional flanges while also offering immediate savings in weight, space and installation time. The Grayloc connector with its metal-to-metal bore seal provides the comparable strength and seal integrity of a welded joint with the added versatility of a mechanical joint. The Grayloc connector was developed in 1954 and has been recognized as the standard for critical service piping and vessel connections in a wide range of industries, applications and environments. The following advantages over conventional flanges make the Grayloc connector an obvious choice where time, cost, reliability and operating efficiency are important considerations.

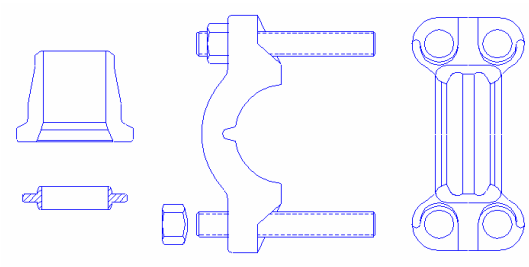
The Grayloc connector:

1) Is significantly lighter and smaller
2) Is shorter, allowing more compact connection lengths
3) Has a reusable metal-to-metal seal ring
4) Has been field proven for over 50 years
5) Is quicker and easier to assemble using only (4) bolts
6) Is assembled using much less bolt torque (up to 70% lower than flange bolting)
7) Clamp can rotate 360° around the hubs to allow the best orientation for bolt tightening
8) Allows equipment such as valves to be installed without the careful alignment of flange bolt holes
9) Has the ability to meet extreme service conditions (vibration, high temperature and thermal shock)
10) Requires no periodic retightening of bolting after the connector has been assembled
11) Has reduced inventory requirements (One clamp size for each pipe size)

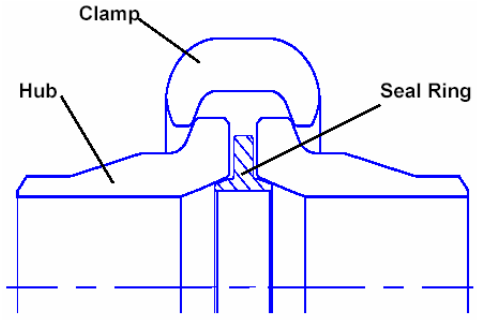
B. The Grayloc Clamp Connector Advantage

The Grayloc connector consists of four basic components:

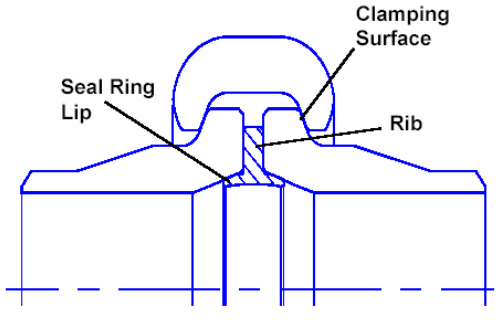
- Hubs
- Seal ring
- Clamp set
- Bolting.



The primary function of the bolting is to draw the two clamp halves together, not to resist internal pressure or external loading. The four bolts of the Grayloc connector, two in each ear of the clamp, provide a 100% redundant bolting system. The sealing integrity will be maintained should any one stud or two opposing studs fail. The reliability of this feature was tested by simultaneous explosive destruction of two opposing nuts on a 2" Grayloc connector that was subjected to a 25,000 psig internal pressure. No leakage resulted. The nuts used on the Grayloc connector have spherical faces that mate to corresponding concave seats in the clamp ears. This prevents excessive bending loads in the studs, which can occur when nut faces are not maintained perpendicular to the centerline of the bolt. The bolting requires no lock washers, or other holding devices, or periodic retightening. This four-bolt clamp complies with the multi-bolt requirements of the ANSI / ASME piping and ASME Boiler and Pressure Vessel Codes. A flange requires a relatively high bolting torque to achieve and maintain the seal. Since the Grayloc clamp connector relies on a clamp to exert the make-up force, the torque required for the clamp bolting is minimal in comparison. This is due to the inherent mechanical advantage produced by the tapered clamp and hub surfaces.



Free Position



Made-Up Position

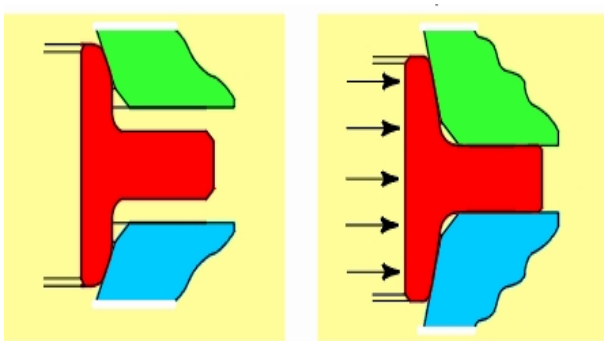
The clamp is the primary pressure-retaining member of the Grayloc connector, not the bolting. During initial make-up of the connector the bolts are tightened, resulting in a large axial tensile force in the clamp, accompanied by a corresponding compressive force in the hubs. Only a small portion of this axial load is required to retain the seal within the hubs. The two-piece clamp configuration insures equal loading around the entire connection. The clamp carries all of the internal pressure loads as well as axial and bending loads transmitted by the pipe. An added degree of flexibility is afforded by the relief groove placed in the center of each clamp segment to allow even distribution of make-up forces even when there are small differences between clamp and hub dimensions. This clamp design

allows for a minimum number of bolts with smaller dimensions than is customary for a standard flange without sacrificing stability.

The hubs are normally butt welded and are manufactured from a material compatible with the pipe or process equipment. The hub contains a tapered sealing surface in the bore, which interfaces with the Grayloc seal ring.

The Grayloc seal ring achieves a self-energized and pressure-energized bore seal. Since the seal is self-energized it will also hold vacuum or external pressures. The seal diameter of a flange ring gaskets is larger than a Grayloc seal. This means the total pressure end load on the flange connection is greater than that of a comparable Grayloc connector. The greater flange pressure end load requires larger bolting as compared to that of a Grayloc clamp connector. The metal Grayloc seal ring consists of a rib and two lips. During make-up, the seal ring lips deflect inward as the connector is assembled. This deflection is controlled and is within the elastic limits of the seal ring material. This deflection is formed because the angle between the rib and lip is slightly smaller that the angle between the hub face and the hub seating surface. Internal pressure will increase this interface bearing load and therefore increase the effectiveness of the seal. "The higher the pressure the better the seal".

Pressure Energized Grayloc Seal



Each Grayloc seal ring is coated with a baked on lubricant; such as, PTFE, molybdenum disulphide, or molybdenum disulphide with graphite to prevent galling of the hub or seal ring sealing surfaces during assembly.

Careful and even make-up of a flange connection is critical to avoid impingement and / or damage of the ring gasket, which can produce leakage during service. Make-up of the Grayloc connection is easier because the seal ring has a rib that provides a positive stop and eliminates any possibility of damaging the seal due to excessive torque during assembly. You cannot overload or "crush" a Grayloc seal ring. The rib of the Grayloc seal ring serves three functions. First, during assembly, the rib insures proper alignment of the seal lips. Secondly, a positive indication of proper seal engagement is provided when the hubs contact the rib during assembly. Lastly, the rib insures that all external piping loads are transferred from one hub, through the rib, and into the other hub without affecting the seal ring lips and resulting seal integrity.

Several unique design features of the Grayloc connector allow it to perform better than a flange joint under conditions of external mechanical loading, thermal fluctuations and vibration.

- The Grayloc geometry and the resulting mechanical advantage embodied in the tapered hub and clamping surfaces serve to isolate the bolting from the axial pressure end load. Specifically, the mechanical

advantage is such that the Grayloc clamp bolting will be subjected to only 10% of the total pressure end load.

- The axial clamp load is uniformly distributed around the entire circumference of the hubs. This continuous and uniform circumferential load distribution is not possible with individual flanges that have individual bolt holes and adjacent localized and discreet load paths.

- The hub / clamp geometry produces monolithic behavior as external piping loads are transmitted through the more rigid hubs leaving the clamp, bolts and seal ring relatively unaffected as discussed above.

- Since the Grayloc hub does not have a bolt circle, the outside diameter of the clamp is smaller than a flange and just slightly larger that the outside diameter of the adjoining pipes. This smaller profile allows for a smaller bending moment geometry thereby making the connector inherently better able to withstand bending forces than a comparable flange.

- The Grayloc seal ring design performs better than a flange ring gasket when subjected to thermal cycling. This is because of the inherent flexibility and self-energizing feature of the seal lips. This flexibility, within the elastic limit of the yield strength of the seal ring material, allows the seal lips to remain in contact with the hub sealing area even though there may be slight dimensional changes in the mating pipe, hubs, clamp, seal ring and bolting produced by variations in temperature and coefficients of thermal expansion. These dimensional changes are common during heat up and cool down cycles.

C. Grayloc Connector Applications

Grayloc connectors have been installed in a wide range of industries, applications and environments for over 50 years. The following is a review of several of these applications. A Grayloc Products User / Applications List is available with specific sizes and design conditions.

Oil & Gas Completion Systems

The Grayloc connector has been installed on onshore and offshore 3,000 – 20,000 psi wellhead completion systems. On offshore platforms in particular, the space allowances for wellheads and trees are critical and connection integrity is important. Grayloc connectors are used on well control equipment, including drilling adapters and reducing hubs, as well as standard wellhead components. The Grayloc seal ring is also used by valve manufacturers to form a seal between the body and bonnet of various types of high-pressure valves.

Oil & Gas Production Manifolds

In manifolds for offshore platforms, both space and weight are critical. The Grayloc connector's design reduces manifold weight, which results in lower structural cost. Grayloc connectors are installed on numerous locations around the world, including the Gulf of Mexico, North Sea and West Africa. The U.S Navy and U.S. Coast Guard has approved the Grayloc connector for shipboard use because of the seal integrity in extreme applications.

Refineries and Petrochemical Plants

Grayloc connectors are used in high temperature and high pressure refining and petrochemical process piping, reactor closures, valves and heat exchanger applications. Grayloc connectors provide an additional level of safety over bolted flanges in critical service areas. Grayloc connectors have proven to be a reliable mechanical joint for 48,000 psi low density polyethylene and 900° F hydrocracking units.

Power / Utilities

Grayloc connectors provide a reliable, quick access connector for primary steam piping systems. Applications in conventional power plants include cleaning access-openings, drip pots, turbine inlets, exhausts and feed water lines. Pressures over 4,000 psi and temperatures of 1000° F have been successfully contained with Grayloc connectors.

Aerospace

NASA is utilizing Grayloc connectors for helium and nitrogen gas purge lines in launch support facilities. Rocket engine test stands, and material testing laboratories have used Grayloc connectors in 6,000 - 10,000 psi pressure ranges and ambient to 1,000° F temperature ranges. The connector has been used in pneumatic launch systems where high frequency vibration exist . NASA continues to use Grayloc connectors in cryogenic test facilities containing liquid hydrogen at –400° F and liquid nitrogen at -320° F.

Environmental – Hazardous Waste Disposal

Grayloc connectors are used in hazardous waste disposal pressure vessel and piping systems. The Grayloc connector is used in the U.S. Army's Explosive Destruction System program where recovered explosively configured chemical munitions are detonated and disposed of in a safe manner. Grayloc connectors have been used in applications with pressures ranging from 2,000 psi to 5,000 psi and temperatures up to 1000° F. The Grayloc metal-to-metal seal has been field proven with zero leak rates at 10^{-6} atm cc/s Helium in these applications.

Food Processing

Grayloc connectors have been installed in supercritical CO_2 extraction processes that involve high pressure and thermal cycling. Coffee decaffeination and food processing units have been using Grayloc connectors for over (20) years. The connectors were selected for these applications based on the sealing integrity of the Grayloc connector in cyclic environments.

Steve Klak *is a registered licensed professional engineer with over twenty-four years of experience with critical service pressure containment equipment. He is the author of patents for instrumentation and piping applications. Professional affiliations include serving as a committee member with ASME, ISA, API and the Gulf Coast Measurement Society. He holds a BS degree in Mechanical Engineering from Union College in Schenectady, NY and a Master of Business Administration from the University of Houston in Houston, TX.*