To Predict ▶ To Design ▶ To Perform

College of Engineering
Department of Mechanical & Industrial Engineering

ME, ECE, IE Capstone Design Programs

Group 34: Improving the Efficiency of Bolted Flange Joint Assembly

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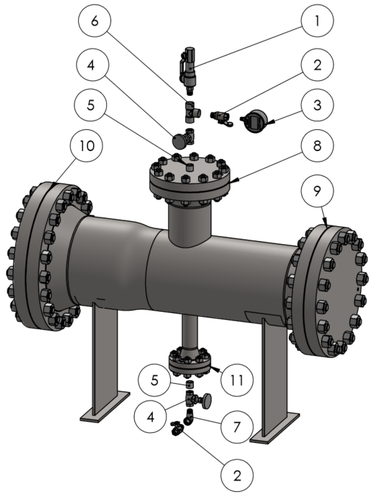
Background & Objectives

- Economically important for refineries and plants
- Ecologically significant for preventing contamination to the environment
- Actualize an apparatus designed to facilitate *testing procedure* to discover most the *time-efficient tightening sequence* while maintaining *a leak-proof system.*
- Confirm *a leak proof system by performing hydrostatic and helium pressure tests*
- Evaluate data collected for flange clearance, bolt elongation, and gasket compression to determine the *effects of tightening sequences on system components*

Engineering Specifications

- System capable of withstanding internal pressure to 500 PSI
- Flanges and gaskets capable of withstanding compression loads of 40,000 lbs
- Bolts able to withstand torques up to 720 ft-lbs



Bill of Materials

NUMBER	COMPONENT
1	SAFETY RELIEF VALVE
2	SHUT OFF VALVES
3	DIGITAL PRESSURE GAUGE
4	GATE VALVES
5	COUPLINGS
6	TEE JOINT
7	L JOINT
8	6” FLANGE ASSEMBLY
9	12” FLANGE ASSEMBLY
10	14” FLANGE ASSEMBLY
11	2” FLANGE ASSEMBLY

Testing & Validation

EACH TEST IS PERFORMED ON 3 DIFFERENT FLANGE SIZES, FOR ALL FOUR TIGHTENING SEQUENCES:

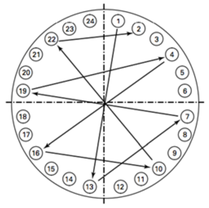
TEST TYPE	ENGINEERING AND QUALITY SPECIFICATIONS	INSTRUMENTATION	OUTCOMES
TIME	MINIMIZE THE BOLTING TIME	STOPWATCH, TORQUE WRENCH	PATTERN EFFICIENCY VS LEGACY STANDARD
FLANGE FACE DISPLACEMENT	EVEN GASKET SEATING WITHIN SEQUENCE	DIGITAL CALIPERS	GASKET LOAD DISTRIBUTION
BOLT ELONGATION	REMAIN BELOW YIELD STRESS	DIGITAL CALIPERS	BOLT LOAD
GASKET COMPRESSION	EVEN GASKET COMPRESSION	DIGITAL CALIPERS	GASKET LOAD DISTRIBUTION
SEAL QUALITY	LEAK RATE = 0 PRESSURE = CONSTANT	PRESSURE GAUGE, HELIUM ANALYZER	PASS/FAIL SEAL RELIABILITY

Sequence Analysis

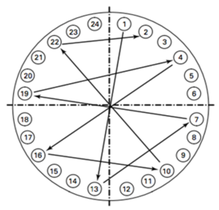
ITEM OF INTEREST	VARIABLE	WEIGHT	LEGACY	MOD LEGACY	QUAD	CIRCULAR
PRESSURE LEAK PASS OR FAIL	L	0/1	1	1	1	1
TIME STDEV	σ_t	4	1	3	2	4
FLANGE CLEARANCE STDEV	σ_c	3	1	2	3	4
BOLT STRESS	B	1	2	1	3	4
GASKET	G	1	1	2	3	4
GRADE			5	21	23	36

$$\text{Sequence Grade} = L\ x\ (\sigma_T + \sigma_C + B + G)$$

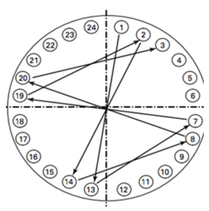
Tightening Sequences



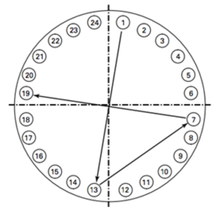
Legacy Cross Pattern



Alternate Legacy Pattern



Quadrant Pattern



Circular Pattern

Specifications and Results

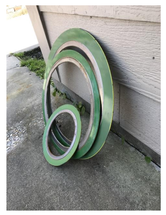
SPECIFICATION	TARGET	RESULT
BOLT CIRCLE	10.62 TO 20.25 (INCHES)	10.62 TO 20.25 (INCHES)
TIGHTENING NUMBER	24 TO 80 (BOLTS)	24 TO 80 (BOLTS)
MOVING NUMBER	58.41 TO 469.8 (INCHES)	58.41 TO 469.8 (INCHES)
ROUND NUMBER	4 (TORQUING ROUNDS)	4 (TORQUING ROUNDS)
GASKET COMPRESSION	0.020 TO 0.050 (INCHES)	0.02 TO 0.042 (INCHES)
BOLT TORQUE	50 TO 533 (FT*LB)	50 TO 533 (FT*LB)
SEATED BOLT STRESS	<125 (KSI)	0 TO 107.5 (KSI)
FINAL BOLT STRESS	<125 (KSI)	0 TO 109.2 (KSI)
AVERAGE SEQUENCE PROCESS TIME	2 TO 30 (MINUTES)	3.5 TO 12.5 (MINUTES)
HELIUM LEAK RATE	$4.3\ X\ 10^{-7}$ TO $4.10\ X\ 10^{-7}$ (CC*ATM/S)	$4.3\ X\ 10^{-7}$ TO $4.10\ X\ 10^{-7}$ (CC*ATM/S)
VESSEL PRESSURE	500 (PSIG)	500 (PSIG)
TIME REDUCTION	10 TO 60 (%)	28 TO 70 (%)

Data Acquisition

Flange Clearance

Digital calipers used to measure flange gap at every bolt after a bolt is torqued.

Gasket Compression

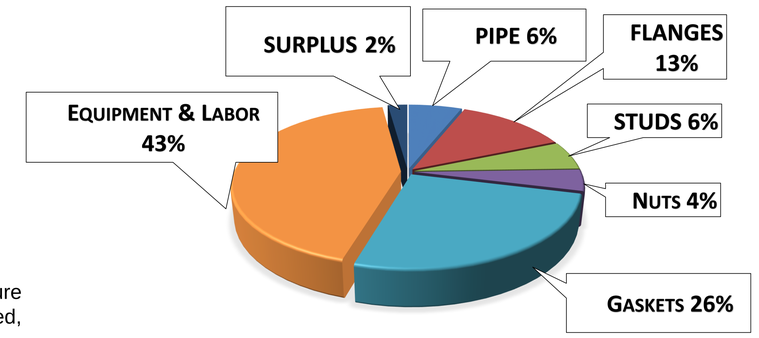


Digital caliper used to measure gasket thickness before seating and after pressure tests. Even compression is also predicted from flange clearance.

Bolt Elongation

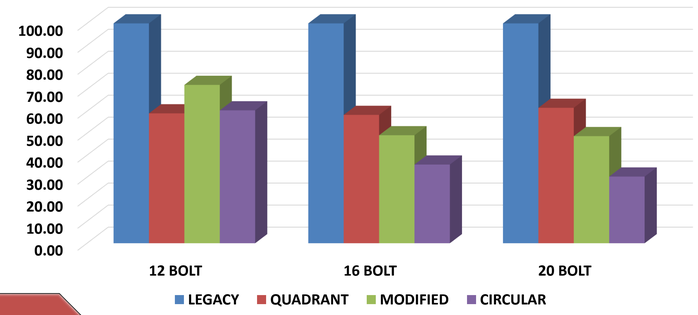
Digital calipers used to measure bolt length before, when seated, and after each tightening sequence. Elongation was used to find stress and strain.

Budget and Milestones



Finalize Apparatus Embodiment → Order All Components for Apparatus Assembly → Cembell Completes Fabrication of Apparatus → Successfully Complete All Tests → Assemble Data & Select Best Tightening Sequence → Present Findings

Tested Time (% Legacy) vs Flange Size and Pattern



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