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Jacket Fabrication for Bombay High Well Platforms

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Synopsis :
Two steel jackets; one for well platforms and the other for living quarters, were designed, fabricated and delivered by Kawasaki Steel Corporation Engineering Division in 1981 to its client: the Oil and Natural Gas Commission of India (ONGC) as one of sizeable orders ever received by Kawasaki Steel of its kind from anywhere. Fabrication sequence, scheduling, man power and production control procedure were elaborately discussed and determined. All the strict requirement for qualities described in ONGC's specification were satisfied and two jackets were shipped on time. This paper outlines the following features: (1) Fabrication (2) Flap-up of side panels (3) Loading out (4) Welding and dimensional control (5) Nondestructive inspection

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Jacket Fabrication for Bombay High Well Platforms*

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Two steel jackets; one for well platforms and the other for living quarters, were designed, fabricated and delivered by Kawasaki Steel Corporation Engineering Division in 1981 to its client: the Oil and Natural Gas Commission of India (ONGC) as one of sizeable orders ever received by Kawasaki Steel of its kind from anywhere. Fabrication sequence, scheduling, man power and production control procedure were elaborately discussed and determined. All the strict requirement for qualities described in ONGC's specification were satisfied and two jackets were shipped on time.
This paper outlines the following features:
(1) Fabrication
(2) Flap-up of side panels
(3) Loading out
(4) Welding and dimensional control
(5) Nondestructive inspection

1 Introduction

Since the development of an offshore oil field in the Gulf of Mexico in 1947, the petroleum output from offshore sources has been steadily increasing, and drilling activities have expanded further into the deep open sea. As an indication of this trend, the production of offshore well platforms has recently reached a marked level of about 300 units/year.

Kawasaki Steel Corporation has supplied, as a steel maker, steel materials for offshore structures of a wide range of specifications up to the present, and since the establishment of the Engineering Division, it has attempted to create and reinforce its working system to meet the increasing demand year after year, involving the production of fabricated structural steel pipes, profile cutting for brace members, node members, legs and wells for jack-up rigs. In 1981, Kawasaki Steel participated in the MPR (SM, SP and SR Well Platforms) Project and the BHS-SLQ (Bombay High South-South Living Quarter) Project of ONGC (Oil and Natural Gas Commission) of India, and received an order for designing and manufacturing two jacket units.

The jackets, one to be used in the SR platform for drilling and the other for SLQ platform for living quarters, were completed in about 10 months after placing order for materials, satisfying every item of the customer's specifications, and were shipped out on schedule. The present paper provides an outline of the production processes concerned.

2 Fabrication

2.1 Work Outline and Specifications

The dimensions of the jacket are shown in **Table 1**. It is a self-standing, four-leg jacket secured to the sea bottom, which is most popular today.

The specifications were based on API RP-2A for the structural system, AWS, ASME and ASTM for welding and inspection, and SSPC for paint coating. The areas not covered by these standards were additionally defined by the work specifications.

2.2 Assembling

Since the fabrication of jacket mainly consisted of space assembly, a key point of the technical management was to contrive the method and sequence for assembling by minimizing the amount of crane work and reducing the manpower requirements.

The SLQ was assembled through the fabrication sequence illustrated in **Fig. 1** on the basis of the following considerations.

(1) The side panels (Row A and B) are space-assembled through flapping-up.

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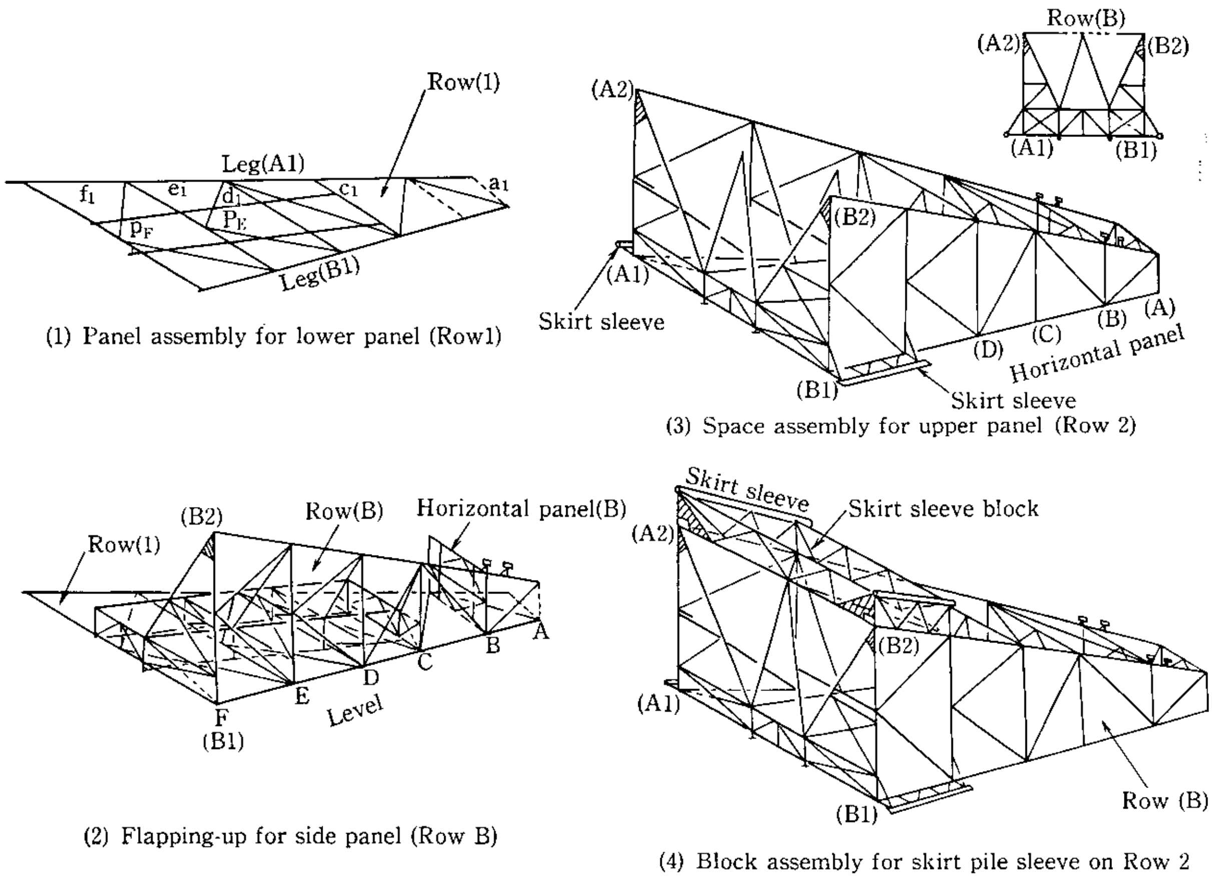
** Engineering Division

Table 1 Dimension of jacket and scope of work

Item		SR jacket	SLQ jacket
Jacket	Height (m)	85	86
	Width (m)	Top : 15.5×6.5 Bottom : 27.8×27	Top : 13.7×15.2 Bottom : 35×36
	Weight (t)	1 290	1 497
Pile	Main	ϕ1 219×t32/44.5×l181/193 m×4	ϕ1 371.6×t38.1×l176 m×4
	Skirt	ϕ1 219×t25/38×l94 m×2	ϕ1371.6×t38.1×l107 m×4
Boat lending		1	2
Others		–	2 bridges (116 t), 2 buoys
Scope		Fabrication	Design fabrication, transportation
Steel material		BS 4360 50D, API-2H ASTM A35, API-5L, etc.	Same as the left column
Dilivery time		Shipped on Oct. 31, 1981	Arrival at Bombay high on Feb. 3rd, 1982



(1) Panel assembly for lower panel (Row1)

(3) Space assembly for upper panel (Row 2)

(2) Flapping-up for side panel (Row B)

(4) Block assembly for skirt pile sleeve on Row 2

Fig. 1 Fabrication sequence for SLQ jacket

(2) Each panel is handled in the state of floor assembly as far as possible up to the final phase, so as to minimize the work in space.

(3) Appurtenances are installed in the floor assembly stage as far as possible.

(4) The skirt pile sleeves of the upper panel (Row 2) are assembled as a block on the floor, and then mounted on the jacket main body.

(5) Prime coating is given to members and panels, and in the space assembly stage, the prime coating is retouched and the final coating is provided.

(6) The pressure and/or leakage tests for inflation and grouting line are carried out after completing the space assembling.

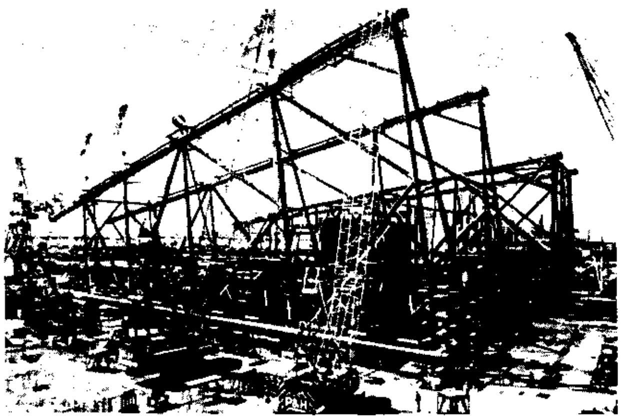


Photo 1 Flapping-up work of a side panel

As the expected results were obtained, it was possible to maintain the initial processes and to level out the work load.

2.3 Flapping-up

Since the flapping-up work to erect side panels after the completion of floor assembling for space assembling involves the simultaneous operation through combined lifting with a number of cranes (see **Photo 1**), it poses a technical problem of maintaining a balanced work load.

During flapping-up, the lower leg (A1 or B1) of the side panel rolls in contact on a semicircular support. The panel was considered as a statically indeterminate structure supported by six supports, to calculate the reaction from each support and the lifting load at each lifting point. However, since these supports did not function as perfect hinges, the panel tended to adversely move both longitudinally and transversely with relative ease, the supports finally becoming unstable. For this reason, various jigs were provided around the lower leg, so that the latter might be kept in hinge-like state during flapping-up. The results are shown in **Fig. 2**. The measured values coincided well with calculated values in $\pm$2–3° range of sling wire inclination (θ), demonstrating the effectiveness of the adopted countermeasure.

2.4 Loading-Out

In the loading-out work, in which the jacket is slowly moved on to a barge, while keeping a good level relationship between the jacket on the land and the barge deck in accordance with changes in the tidal level, the key point is smooth ballasting based on the calculation of the load distribution on the barge corresponding to the movement of the jacket.

In the present work, the load distribution by the jacket weight was calculated by assuming a step-like distribution as shown in **Fig. 3**, and the ballasting was

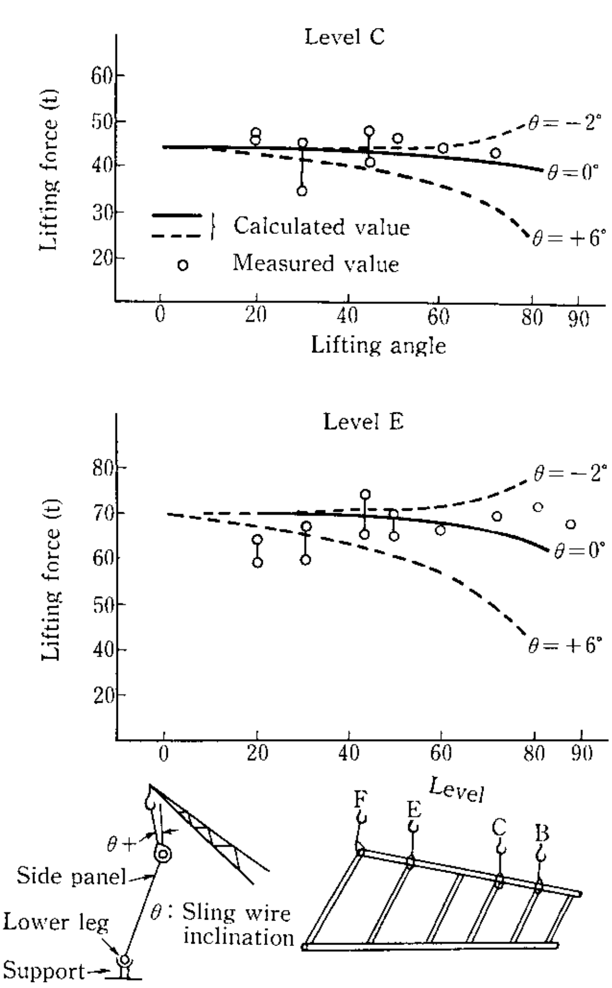


Fig. 2 Comparison of lifting force between estimated and measured

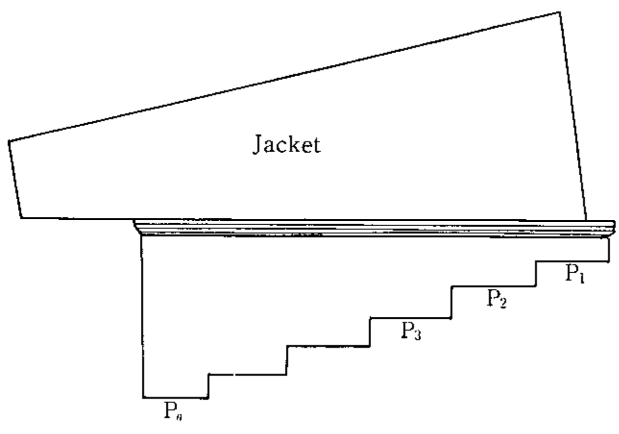


Fig. 3 Load distribution model on barge by jacket weight

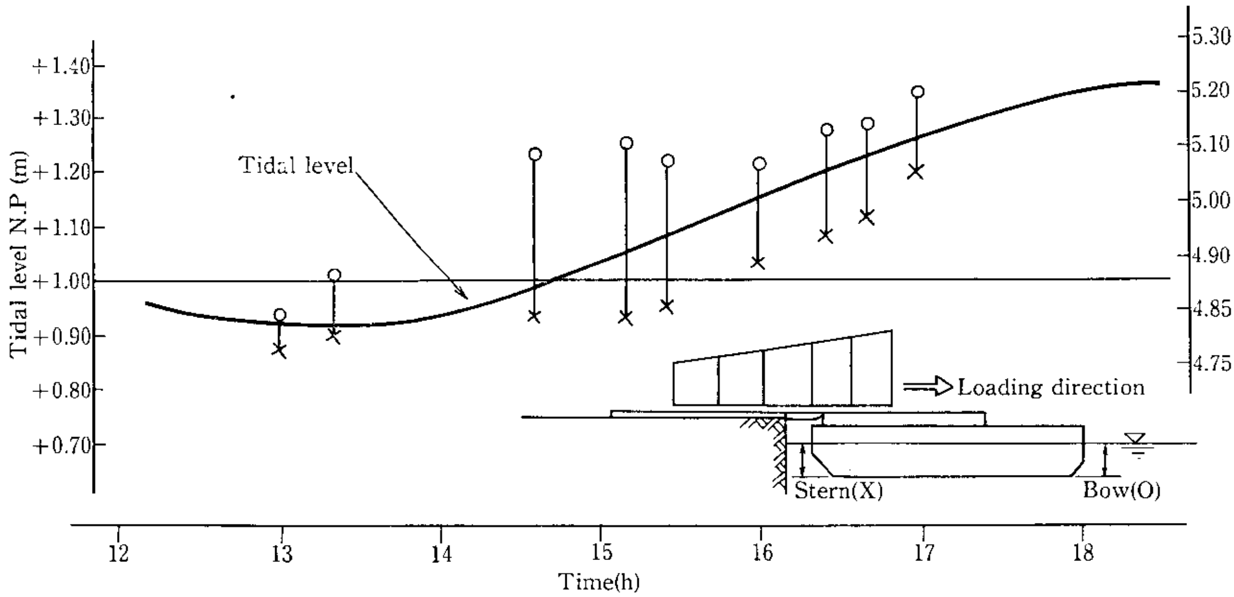


Fig. 4 Change of tidal level and draft controlled by ballasting

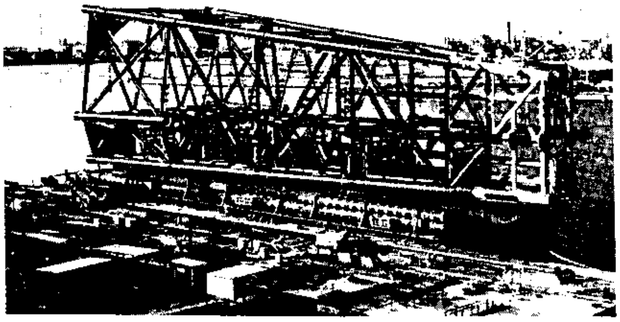


Photo 2 SR jacket placed on a barge

Photo 3 Welded joint of the jackets

directed on the basis of the results thus obtained. The result is shown in **Fig. 4**, suggesting satisfactory draft control. The SR jacket placed on a barge is shown in **Photo 2**.

2.5 Welding

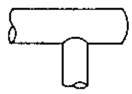
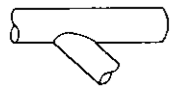
Welding of this jacket involved T-, K- and Y-joints at tubular joint (see **Photo 3**) and circumferential butt joints at a ratio of 7:3, approximately. Since T-, K- and Y-joints were principally one-side welded by shielded metal arc welding, it constituted an important problem in the quality control for welds to keep the root gaps within an appropriate tolerance.

For this reason, it was considered essential to improve the accuracy of fabrication and fitting for braces and to predict the contraction of root gap exactly at time of tack welding. First, the dimensions of the profile cutting of braces were controlled strictly, and the braces were used as templates for assembling. Moreover, accurate fitting was adopted with exact positions marked by using paper templates for setting.

In welding, temporary pieces were not used as far as possible so as to reduce retouching works. In order to minimize the deformation by welding caused by this method, a few of separate predictions for T-joints and K- and Y-joints were used for reference for the control of setting of braces.

Table 2 shows measured values of root gaps on the side panel (Row A) in the floor assembling and on the upper panel (Row 2) in the space assembling. It is evident that in the earlier stage of assembling on Row A where setting and fitting of legs and braces

Table 2 An example of measured root gap of T-, K-, and Y-joint

Item		T-joint				K-·Y-joint			
		12 O'clock	3	6	9	12 O'clock	Heal	6	Toe
Row A (Floor assembly)	Average/Number of samples	2.9/11	4.7/12	3.3/12	3.6/12	3.3/16	3.2/16	4.3/16	5.6/16
	Max.	5.0	8.0	5.7	7.2	4.9	6.9	6.6	9.7
	Min.	0	1.9	0	1.5	2.1	2.0	3.0	2.9
	Number of out of tolerance	1	2	1	2	0	2	1	4
Row 2 (Space assembly)	Average/Number of samples	6.1/12	7.4/12	3.3/12	3.6/12	4.7/14	3.8/13	4.5/14	5.8/14
	Max.	13.8	14.0	14.3	12.8	7.2	8.4	8.0	8.9
	Min.	1.0	3.0	2.8	2.6	2.8	1.0	2.0	2.7
	Number of out of tolerance	5	7	6	6	2	2	2	5
		 12 O'clock 9◯3 6				 12 O'clock Toe◯Heal 6 O'clock			

Note) Tolerance: 1.6-6.4mm

could be made freely, the root gaps were controlled properly.

On the other hand, in Row 2 where leg spacings had been restrained by the horizontal panels and various braces, the adjustment at the time of tack welding was often inadequate, and consequently larger root gaps occurred frequently. These gaps were remedied by the modification of profile through buttering.

3 Inspection

3.1 Dimensional Inspection

A high degree of accuracy in checking was required for the straightness of legs and piles, and for the flatness of the horizontal panel (level A) of the jacket top which was to be joined to the deck frame in the field.

The allowable tolerance was based on the regulation of API RP-2A "Fixed Offshore Structure", as shown in **Table 3**. In the present work, owing to the high accuracy setting and fitting of members described in Par. 2.5, the work accuracy could be held within the allowable tolerances.

3.2 Nondestructive Inspection for Welds

For the inspection of steel pipe welds, it is obligatory to employ radiographic testing (RT) for the circumferential butt joints, and ultrasonic testing (UT) for the T-, K- and Y-joints in tubular joints.

The application of UT to the T-, K- and Y-joints

Table 3 Dimensional tolerances

Item		Tolerance
Steel pipe	circumference	1% of nominal outside diameter Max.: 6 mm
	Circumferential length	±1% of naminal circumferential length Max.: 12 mm
Jacket	Width of leg center on jacket top	± 6 mm
	Flatness of jacket top	± 6 mm
	Corner angle of horizontal panel	± 1
	Bending for leg	± 6 mm
Pile	Warp	3 mm: For every 3m increase in length 13 mm: For over 12m
	Squareness of pipe end	1.6 mm per 300 mm of out side diameter Max.: 6 mm

under one-side welding has involved numerous problems because various standards require different procedures and evaluations for defects. However, as the inspection procedure and acceptance criteria of UT for T-, K- and Y-joints of tubular joints were published in 1980 as the API RP-2X, the latter was adopted in the present work.

The API evaluation has three levels, A, C and F, which are summarized in **Table 4**. For practical purposes, it is of capital importance whether to adopt A or C.

As is evident from **Table 4**, level C is lenient in permissible defect, but level C requires measuring of the width and length of defects.

Thus, there may arise a practical problem in that

Table 4 API RP-2X reject criteria for tubular T-, K-, and Y-joint

Level	A	C	F
Conception	Workmanship quality	Evaluation based on "fitness-for-purpose" quality	Specific fitness-for-purpose quality
Reference reflector	1.6 mm ϕ side-drilled hole and and 1.6 mm deep slot	same as the left	same as the left
Reference level (DAC)	50−100%	100%	100%
Acceptance criteria	Evaluation based on ampiltude and length of defect with classification of the kind of defects above 50% DAC	Evaluation based on length and width of defects with classification of the kind of defects above 100% DAC	1. All defects including larger than level C shall be permitted to evaluate 2. To estimate occtual defect dimensions 3. The static strength based on remaining net section should be adequate 4. Brittle fracture should be precluded by demonstrating the fracture mechanics
Spherical defects	1. Isolated, ramdam print defects are permitted 2. Aligned print defects shall be evaluated as linear ones and judged by length 3. Clusteved point defects shall be judged by amplitude and density	1. Isolated, ramdom spherical defects are permitted 2. Clustered porosity above 100 % DAC shall be judged by density	
Cylindrical or planner defects	Judged by defect lenght above 50% to 100% DAC and 100% DAC	Judged by defect length and withd above 100% DAC	
All defects	Permissible under 50% DAC	Permissible under 100% DAC	

the acceptable length varies widely for 1 mm or less difference in detected defect, depending upon the evaluation of width.

On the other hand, level A evaluation is made on the basis of the amplitude of reflection and the length of defect alone. The concept evaluation in level A is similar to that for JIS and ASME standards. For this reason, level A was adopted.

However, with respect to the reference level, 2X was not adopted as it was, but certain modification was made so that the acceptance criteria would correspond to those in the AWS and ASME.

The UT operators were trained for the purpose of improving the reproducibility in the detection of defects by using model joints in which false indications were embedded, so as to avoid troubles which were predicted to occur through the adoption of new criteria.

Consequently, the ratio of successful detection by UT of defects (the ratio of the number of detected defects to that of existing defects) was as high as 90% for the one-side welding in T-, K- and Y-joints for which poor reproducibility had been claimed. Anticipated troubles did not occur at all.

4 Conclusion

In order to avoid installation during the monsoon season, a strict delivery term was always set in the work schedule for the ONGC platforms. However, the assembly of both SR and SLQ was completed on schedule at Kawasaki Steel's Harima Fabrication Center, thus establishing a high reputation of Kawasaki Steel for the fabrication of offshore structures.
The authors are deeply grateful to those concerned with the present work, including those in the affiliated companies, cooperative firms, clients and the third-party inspectors.