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FUJI'S SF_6 GAS CIRCUIT BREAKERS AND CUBICLES DELIVERED TO DOW CHEMICAL U.S.A.

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1 INTRODUCTION

Recently, the construction of a new cogeneration power plant at Dow's Texas Operations was completed.

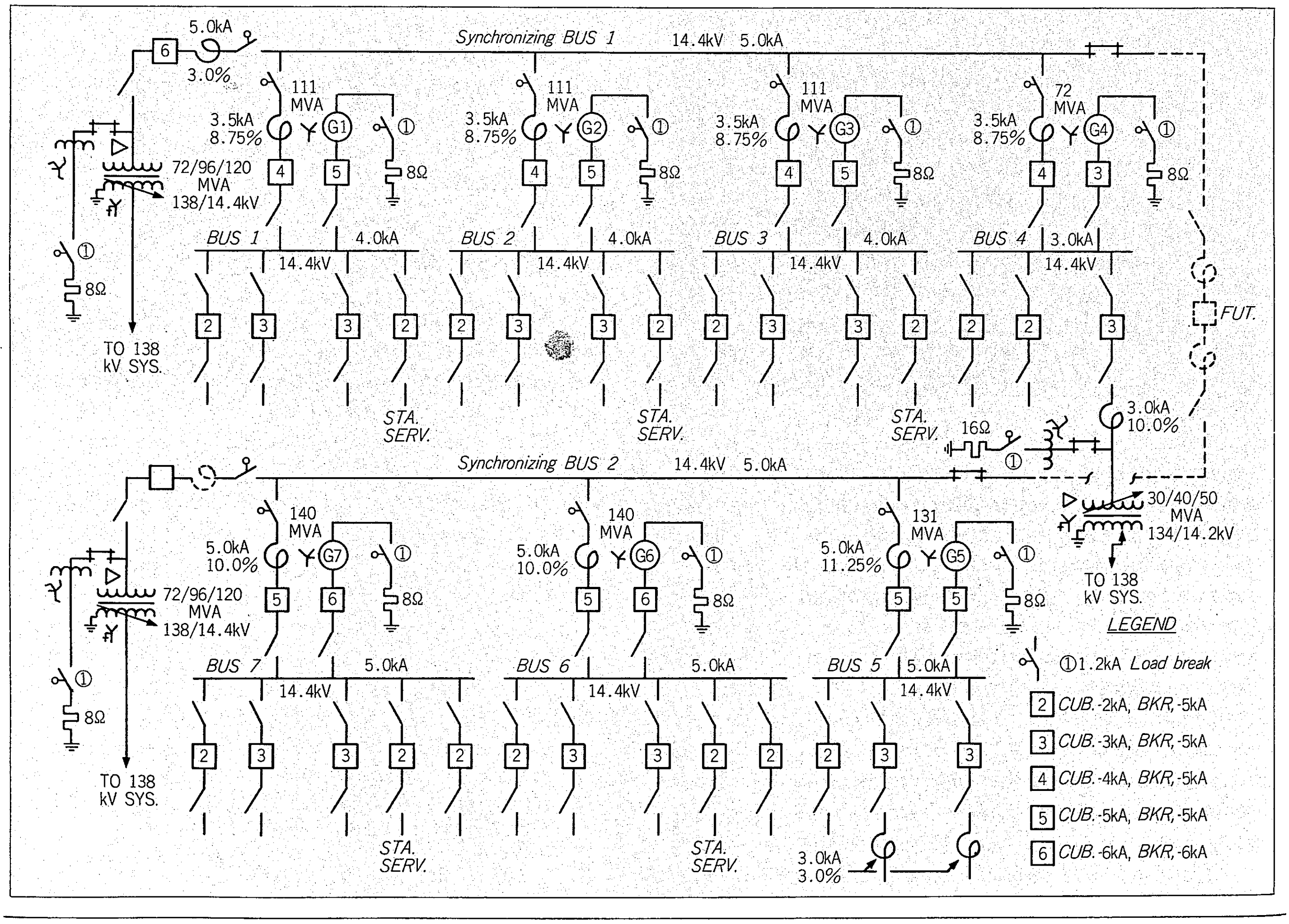
Various types of electrical equipments were provided for the project including fourty-two (42) SF_6 circuit breakers model BAG002RR/RP and cubicles delivered by Fuji.

This model BAG002RR/RP circuit breaker is a large capacity series for the medium voltage class 12 ... 36 kV with a symmetrical breaking capability up to 73 kA (at 14.4 kV) and a continuous rated current up to 6 kA. To date Fuji has delivered a total of seventy-six (76) model BAG002RR/RP circuit breakers and cubicles to Dow Chemical U.S.A.

2 SYSTEM CONFIGURATION

Fig. 1 is the 14.4 kV one line diagram of the power

Fig. 1 14.4 kV one line



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plant. The synchronous bus configuration where each generator and its associated distribution bus is connected through a current limiting reactor to a synchronous bus and regulating transformer was selected over the unit-transformer method. This configuration allows easy distribution of power at the generation voltage level to large loads adjacent to the facility, plus transformation of power to or from the 138 kV grid. Furthermore, maintaining healthy system voltages during turbine/generator outages can be easily accomplished by controlling the synchronous bus voltage with the regulating transformer.

3 CIRCUIT BREAKERS

The breakers selected were single pressure puffer type SF_6 (sulfur-hexafluoride) gas circuit breakers like that shown in *Fig. 2*. These breakers use the gas for insulating and arc-quenching purposes. The high gas pressure required for arc-quenching during the interrupting process is produced by the puffer device shown in *Fig. 3*. Each breaker has a self-contained electrically operated hydraulic mechanism with one close and two trip coils. Both the gas and hydraulic system are monitored and the user is provided with the following alarms:

- Low SF_6 gas pressure
- Low SF_6 gas pressure operating (close and trip) lockout
- High oil pressure
- Low oil pressure
- Low oil pressure closing lockout
- Low oil pressure tripping lockout
- Loss of nitrogen gas
- Long oil pump operation
- Failure of oil pump motor source

Each breaker was designed to meet or exceed requirements of ANSI C37 standards (1), (2), (3), (4), (5), (6) and carries the following ratings:

Model	BAG002RR
Rated continuous current	5.0 or 6.0 kA
Rated voltage	14.4 kV
Rated maximum voltage	15.5 kV
Rated minimum voltage	12.0 kV
Rated voltage range factor	1.0
Rated maximum interrupting capability	63 kA Sym. 75.6 kA Asym.
S factor	1.2
Rated close and latch capability	170 kA Peak
Short time current (3 seconds)	63 kA
Rated BIL	110 kV
Rated low frequency withstand	50 kV
Rated interrupting time	5 cycles (max)

The utilization of large current limiting reactors closely coupled to the switchgear and generators with higher than normal X/R ratios suggested that special consideration should be given to interruption of symmetrical faults with high transient recovery voltage (TRV) rates and interruption of asymmetrical faults with delayed current zeros.

TRV Analysis and Test - Calculation of TRV rates were performed by Fuji after system reactance and capacitance data was obtained. A calculating method by Callow (7) which assumes no dampening and converts double frequency networks into a single frequency equivalent was used. This method is less tedious and offers very conservative

Fig. 2 SF_6 puffer circuit breaker outline

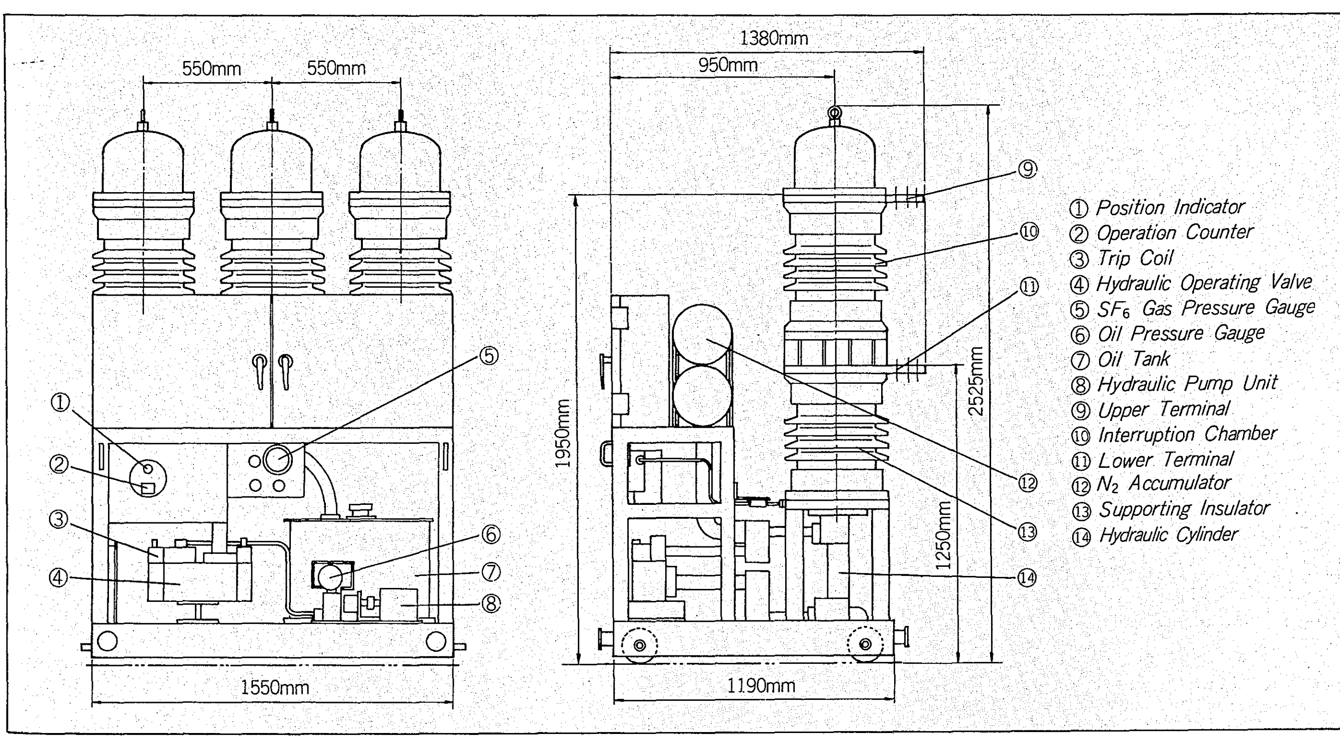


Fig. 3 Interruption sequence of SF_6 puffer circuit breaker

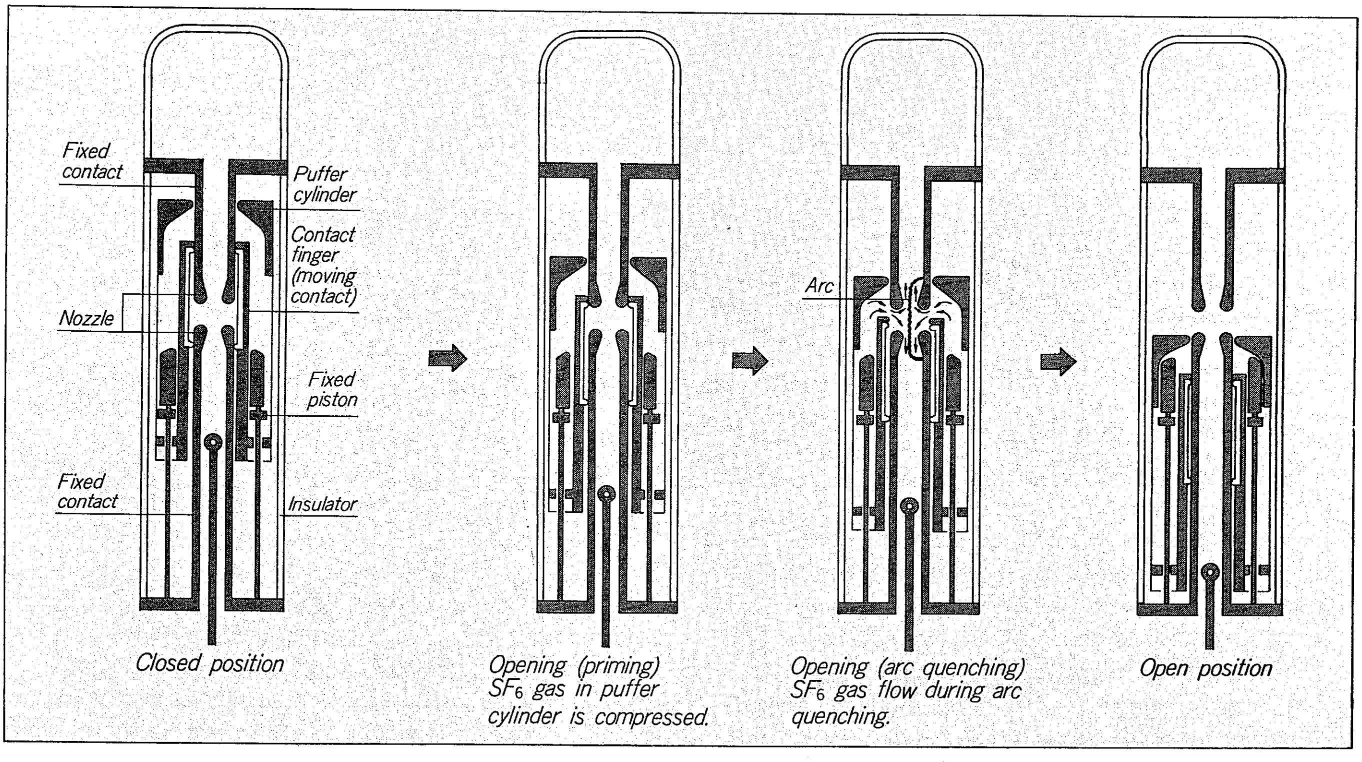
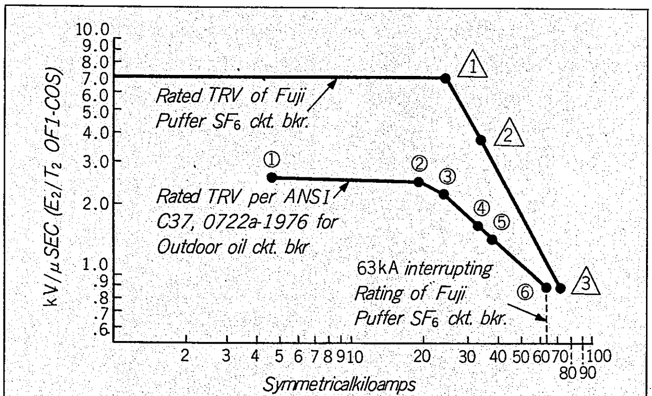
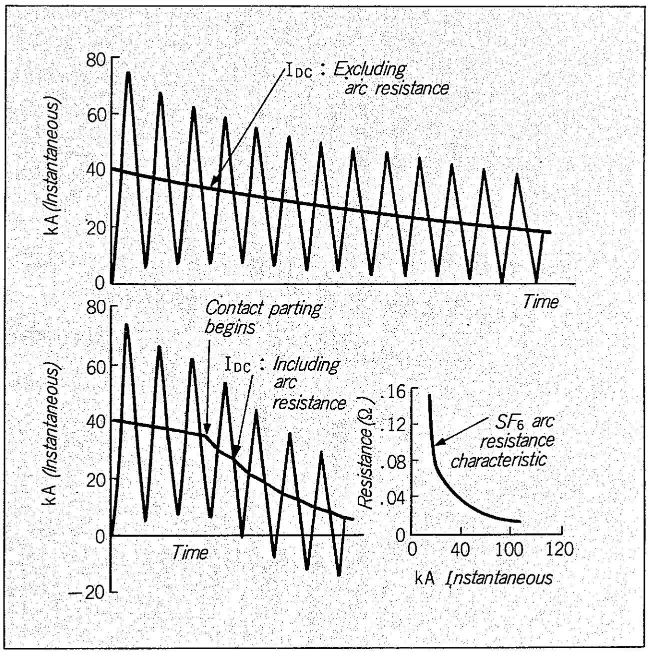


Fig. 4 SF_6 GCB TRV capability



	ANSI oil			Puffer SF_6		
	kA	E_2	T_2	kA	E_2	T_2
①	4.41	34.1	13.2			
②	18.9	32.9	13.2			
③	24.0	32.3	14.9	△1 24.0	41.3	8.0
④	34.0	31.5	20.1	△2 34.0	41.0	10.9
⑤	37.8	31.2	22.1			
⑥	63.0	29.1	23.0			
				△3 73.0	39.0	44.0

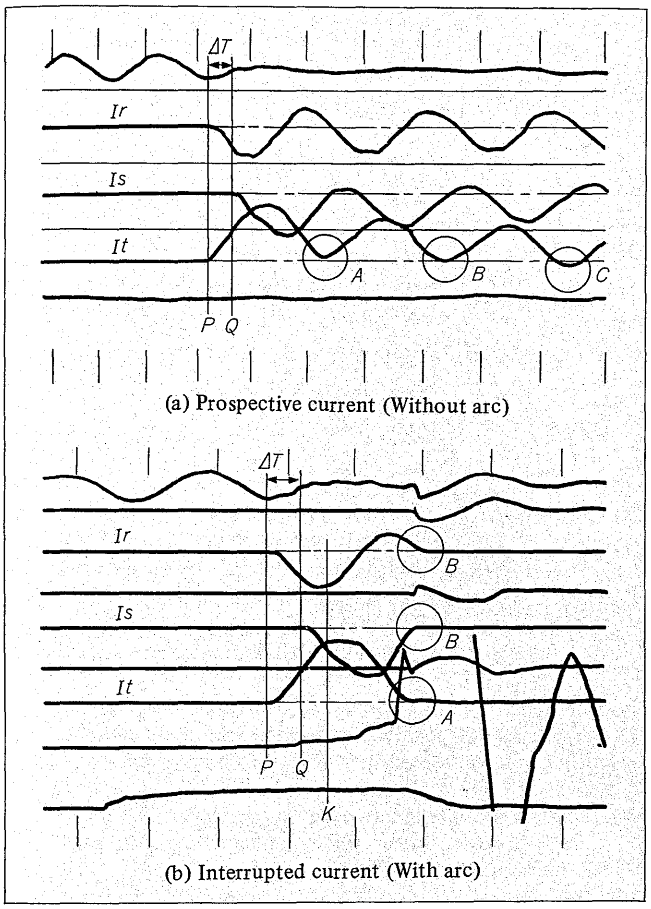
Fig. 5 Delayed current zero fault current for typical generator three phase fault



results that can be easily duplicated in a synthetic testing laboratory. The calculations were performed as the first breaker pole clears one phase of a three phase ungrounded fault. The results showed that TRV rates for several breakers were exceeding ANSI C37.0722a–1974 (4) requirements for outdoor oil breakers to which the SF_6 breakers had been previously tested. One breaker was retested by Fuji to verify the required capability. The results are shown on *Fig. 4.*

Delayed Current Zero Fault Analysis and Test - Generator asymmetrical fault currents without current zeros for several cycles are due to the subtransient a.c. component decaying faster than the d.c. component and are well described by Graber, Zurich and Gysel (8). Calculations assuming unloaded prefault conditions were performed by the breaker manufacturer to determine:

Fig. 6 Oscillograms of breaking test under delayed current zero fault



1. Offset magnitude and duration for both three phase and line to line faults without the modifying effect of breaker action.
2. How well the arc resistence characteristic of the SF_6 breaker would force the current zero for both types of faults.

Fig. 5 shows an example of the calculated results. One breaker was tested by Fuji to verify the required current zero forcing capability.

Fig. 6 shows one example of oscillogram for interruption under the delayed current zero fault.

Fig. 6 (a) shows the prospective current without arc. The current of phase t (It) does not intersect zero level at points A and B. To get the current with delayed zero in the laboratory testing station, at first phases of r and t are short circuited at point P and after ΔT(ms) phase s is short circuited at point Q.

Fig. 6 (b) shows that the current It is forcibly interrupted at point A with intersecting zero level due to arc resistance between breaking contacts opened at point K.

4 STATION CUBICLE SWITCHGEAR

Each SF_6 breaker as shown in *Fig. 7* is housed within a metal-clad type cubicle containing all required buswork, insulators, disconnect switches, potential transformers and current transformers. Each distribution bus is composed of five to seven cubicles grouped together as shown in *Fig. 8*. Design features of these cubicles include:

- Compartmental type design where breaker, main bus, disconnect switches, potential transformers, outgoing bus or feeder cable terminations and low voltage control are separated by steel barriers.
- Pressure relief blow out panels for each compartment that are designed to limit cubicle damage from the expansion of ionized gases associated with a large internal fault.
- Fully insulated 50°C rise over 40°C ambient copper bus.
- Worm gear operated draw-out potential transformer trucks including bus side connection safety shutters.

Fig. 7 Outerview of SF_6 gas circuit breaker Model BAG 002 RR

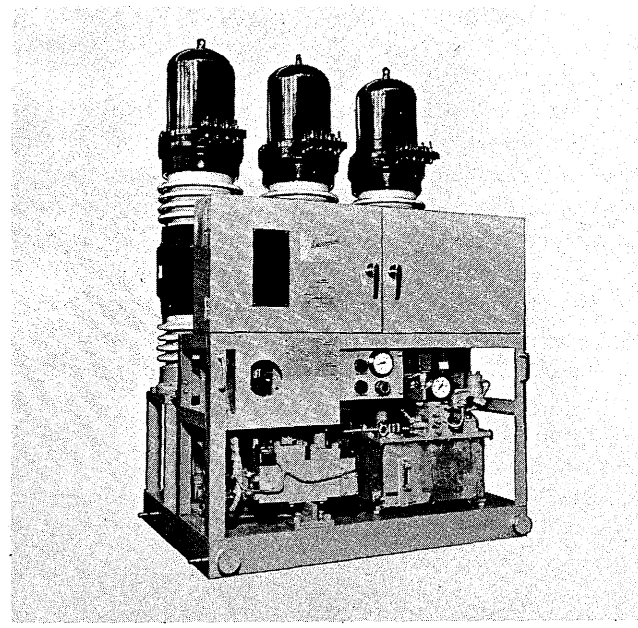
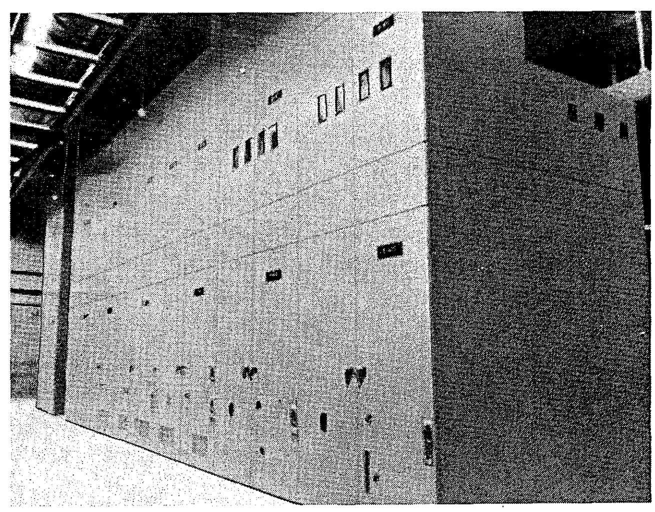


Fig. 8 Station cubicle lineup



- Seal-off bushings and stand-off insulators made of cycloaliphatic epoxy resin.
- High pressure contact knife blade disconnect switches, worm gear operated.
- Blow out proof viewports for disconnect switch compartments.
- Illuminated compartments.
- Humidistat controlled space heaters in main bus compartment, breaker position controlled space heaters in all other compartments.
- Key interlocks for breaker and disconnect switches.
- Current transformers rated 0.3% at B2.0 metering class and C-200 or C-400 relaying class per ANSI C57.13–1968 (9).
- Potential transformers rated 0.3% at W, X, Y, Z burden, 1.2% at ZZ burden and 400 VA thermal per ANSI C57.13–1968 (9).
- Inspection windows for SF_6 gas pressure gauge, operation counter and position indication, hydraulic oil level gauge and hydraulic oil pressure gauge.
- Welded steel frame with bolt-on panels or access doors of eleven gauge steel minimum.
- Aluminum plates for bus duct or feeder cable termination compartment entrances.
- Phase barriers between non-insulated energized parts in the disconnect switch and breaker compartments.

Feeder breaker cubicles are identical to generator and synchronous bus tie breaker cubicles except for the equipment provided within the compartment above the breaker. This compartment comtains a disconnect switch and bus arranged for terminating feeder cables rather than potential transformers and bus connections for isolated phase bus duct.

Switchgear cubicle short circuit and voltage ratings are equivalent to the breaker ratings. Continuous ampacity ratings of cubicle bus and disconnect switches are shown on *Fig. 1*, however all breaker elements carry either a 5000 or 600 amp rating and are physically interchangable.

5 ACKNOWLEDGEMENT

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