APPENDIX A: Description of Substation Damage Database Structure

A.1 General Description of Database

The purpose of the database is to document poor and good seismic performance of substation equipment. The database contains information about damaged and undamaged substation equipment from the following earthquakes

- San Fernando - 1971
- Point Mugu - 1973
- Santa Barbara -1978
- Coalinga - 1983
- Morgan Hill - 1984
- North Palm Springs - 1986
- Whittier Narrows (mainshock and aftershock) - 1987
- Tejon Ranch - 1988
- Sierra Madre - 1991
- Loma Prieta - 1989
- Landers - 1992
- Northridge - 1994

The majority of data relates to equipment operating at 220/230 kV and 500 kV. In a very few cases, damage to 60 kV equipment is documented. Equipment in the database is owned by Pacific Gas & Electric, Los Angeles Department of Water and Power, Southern California Edison and the California Department of Water Resources.

A.2 Format of Database

The Substation Damage Database has been saved in an EXCEL 97 spreadsheet. The data is organized into four data sheets to simplify viewing. The first, entitled "All-Data", contains all of the data for each piece of equipment and should be considered the master data sheet. All new entries or modifications should be completed on this sheet.

The second, third and fourth sheets are subsets of the first and are developed by referencing the first sheet. No modifications or data entry should be made on any of these sheets. The second sheet, entitled "Facility", is limited to information describing the facility (Facility Data) at which the item of equipment is located and also describes the impact of the earthquake at the facility. The third data sheet, entitled "Equipment", describes the item of equipment (Equipment Data), how it is installed, and its damage (for damaged equipment). The fourth data sheet, entitled "Comments", contains some of the fields that have long comments.

Each record of the database corresponds to a damaged equipment item or a group of identical undamaged equipment items. Each record contains information on the earthquake, the facility (typically a substation), and the item of equipment. This organization generates a larger database than is necessary, since earthquake and facility data is repeated for each equipment item.

The following commentary defines each field in the database and gives explanatory notes as appropriate. Since searches for data cannot be done if different terminology is used to enter data, it is desirable to standardize terminology used for data entered into the database. Lists of preferred terms to be used as the contents of a field are shown in **bold** face type.

A.3 Earthquake Data Fields (columns A through 0)

The data contained in this part of the database is available, in general, from geoscience sources such as the United States Geological Survey (USGS), California Division of Mines and Geology (CDMG), National Earthquake Information Center rather than directly from utilities or the Electric Power Research Institute (EPRI). For damaging earthquakes most of the data is available from one of the above sources or in an Earthquake Engineering Research Institute (EERI) reconnaissance report. In general, data that best describes the situation relative to power system performance will be used. In cases where strong motion records at the substation site are not available, ground motions have been supplied by Paul Sommerville of Woodward Clyde Consultants. If different estimates for various parameters are available from reputable sources, this is noted in the appropriate sections. References of data are provided for earthquake parameters such as epicenter, focal depth, magnitude, fault plane solutions, etc.

Col.	Field Name	Description	Examples
A	**EQ_NAME**	Common name normally used.	*Whittier Narrows, Tejon Ranch, Loma Prieta*
B	**EQ_DATE**	Month, day, year separated by a slash. Leading zeros for one digit numbers can, but need not be, used.	*01/06/89, or 1/6/89 for 6th of January 1989*
C	**EQ_TIME**	Local time is used as it is easier to relate power system load at the time of the earthquake. Use local time with a 24 hour clock indicating hour, minute, and seconds To convert from Pacific Daylight Savings Time to UTC add 7 hours. To convert Pacific Time to UTC time add 8 hours.	*15:10:12* corresponds to 10 minutes, 12 seconds after 3 p.m.
D	**EPICNTR_LAT**	Epicenter Latitude is expressed in degrees and decimal degrees to 0.001 degrees. This designation will also be used for designating facility locations and the location of strong motion instruments. This is the most convenient form to perform calculations. Note that a resolution of 0.001 minutes is about 6 ft. in California. If it is assumed that substation location data is to be obtained from 7.5 minute series USGS maps, the resolution using a x8 loop with a calibrated reticule (with a resolution of .005" per division) would allow a resolution of about 0.0025". This would correspond to about 0.002 minutes. It is questionable if a straight line can be drawn parallel to the map boundary with an accuracy of better than 0.01". Thus, while a resolution of 0.001 minutes may be used, it is estimated that the accuracy will be no better than .01 minutes. Epicenter Coordinates expressed in degrees and decimal degrees to .001 gives a resolution of about 350 ft. To convert from decimal degrees to minutes multiply the decimal part by 60.0 to give minutes to 0.001 minutes.	An example of Latitude is *37.412N*.

E	**EPICNTR_LONG**	Epicenter Longitude	An example of Longitude is *121.412W*
F	**MAGNITUDE**	Local Richter (M_L) is used for consistancy. Other magnitudes can be noted in the EQ Commentary using the following abbreviations: Surface Wave (M_S), Moment (M_W)	*6.3*
G	**FOCAL_DEPTH**	depth is in km	*12*
H	**FAULT_TYPE**	The standardized values are: **Strike-Slip, Strike-Slip-Oblique, Normal, Normal-Oblique, Reverse, Reverse-Oblique, Thrust, Thrust-Oblique.**	
I	**FAULT_SOLU1**	Strike (azimuth clockwise from North) Source of data should be referenced in EQ_COMMENT field.	
J	**FAULT_SOLU2**	Dip (degrees and direction of dip) Source of data should be referenced in EQ_COMMENT field.	
K	**FAULT_SOLU3**	Slip (degrees) Source of data should be referenced in EQ_COMMENT field.	
L	**ALT_FAULT_SOLU**	Source of data should be referenced in EQ_COMMENT field.	
M	**MAX_MMI**	Maximum MMI. If the Intensity is expressed in other units, such as, Rossi-Forel (**RF**) or MKS (**MKS**), it should be converted to MMI.	Note that Arabic rather than Roman numerals are used, for example: *8*.
N	**EQ_COMMENT**	This field may contain the following information: • The source of the earthquake data by reference to a citation given in the field REFERENCES. • The number of strong-motion records and their source. • The existence of a MMI map. (The availability of information should be indicated by one of three terms: f for item on file, y for yes for available with source in references, n for no.) • A note if there has been significant directionality for this earthquake • A note if there have been intensity anomalies for this earthquake • List of Strong Motion Records associated with substation: Number of records, record identification (source and designation).	
O	**REFERENCES**	Reports with source data for the earthquake should be referenced here. This would include company reports, and reports from other organizations such as EERI, EPRI, USGS, CDMG, BSSA, etc. Sources for fault plane solutions, and MM Intensity should be cited.	

A.4 Substation Data Fields (columns P through AJ)

For brevity, all facilities that contain substation-like equipment will be called substations. They would include switchyards and switching facilities associated with power generating plants. To simplify searches of the database, standardized names are used (shown in **bold** letters). In general, field contents should be limited to one of these choices.

Col.	Field Name	Description
P	**FACIL_NAME**	Facility name
Q	**FACIL_OWN**	Standardized values are **PG&E, SCE, LADWP, CDWR, SDGE**.
R	**TYPE_FACIL**	There is no industry standard for terminology defining various types of substations. In general, the classification as to the type of substation is not important, as the emphasis is on the equipment and its voltage level rather than the facility that it is in. This database uses the following terminology. **Transmission SS** (SubStation) These stations are used for the transmission of bulk power at voltages of 110 kV and above. This type of substation may be referred to as a transmission, subtransmission, receiving, switching substation, and switchyards at transmission voltages. **Distribution SS** (SubStation) These substations typically have output voltages below 34 kV. Supply voltages to distribution substations will typically be 60 kV although higher voltages can be used. The substation would have switchyard equipment at supply and distribution voltages. **Power Station** These facilities have step-up transformers and switchyards to feed power into the transmission network. **DC Converter S** These facilities have specialized equipment associated with DC Converter part of the stations as well as transitional substation facilities, typically at transmission voltage.
S	**FACIL_ADD**	Street address or location
T	**FACIL_LAT**	Facility latitude at the control house will be used. See comments about resolution and accuracy under Epicenter Coordinates in earthquake data section.
U	**FACIL_LONG**	Facility longitude at the control house will be used. See comments about resolution and accuracy under Epicenter Coordinates in earthquake data section.
V	**EPICEN_DIST**	Epicentral distance (km)
W	**DIST_RUPT**	Closest distance to fault rupture surface (Distance to Rupture) (km)
X	**SITE_MMI**	Site MM Intensity. Reference to the documentation supporting MMI should be given in the Ground Motion Commentary field. Is the MMI based on an overall intensity map or is it based on observed damage adjacent to the site?
Y	**EST__PEAK_ACC**	Estimated Peak Acceleration. This field has the effective peak acceleration if the site had a strong motion instrument, or an estimate of the effective peak ground acceleration based on synthetic strong ground motions generated by Paul Somerville. The basis for the acceleration estimate is given under Ground Motion Commentary.
Z	**0.1_SA**	0.1 second spectral acceleration. This field will have the 5% damped, 0.1 second spectral acceleration if the site had a strong motion instrument, or an estimate of the 0.1 second spectral acceleration based on synthetic strong ground motions generated by Paul Somerville. The basis for the acceleration estimate is given under Ground Motion Commentary.

AA	**0.2_SA**	0.2 second spectral acceleration. This field will have the 5% damped, 0.2 second spectral acceleration if the site had a strong motion instrument, or an estimate of the 0.2 second spectral acceleration based on synthetic strong ground motions generated by Paul Somerville. The basis for the acceleration estimate is given under Ground Motion Commentary.
AB	**0.3_SA**	0.3 second spectral acceleration. This field will have the 5% damped, 0.3 second spectral acceleration if the site had a strong motion instrument, or an estimate of the 0.3 second spectral acceleration based on synthetic strong ground motions generated by Paul Somerville. The basis for the acceleration estimate is given under Ground Motion Commentary.
AC	**SM_RECORD**	**Yes** indicates there is a strong motion record from the site, **NO** indicates there is none.
AD	**SOIL_TYPE**	Where possible Uniform Building Code 1997 site classifications have been used: S1 S2 S3 S4 Often a more complete description of the soil/bedrock condition is included. In cases where detailed information is not available, what is desired is a classification of the site conditions to indicate the degree that they will affect facilities at the site through liquefaction, subsidence, or amplified ground motions. Although surface conditions or superficial site preparations often done at substations will not adequately characterize the site the following classification is suggested **Liquefiable** - Subsurface is composed of poorly consolidated material, with a high water table. In addition to liquefaction, problems associated with soft sites also may be present. **Soft** - Subsurface is composed of moderately consolidated materials with a depth greater than several feet. The site would be susceptible to nonlinear soil response such as slumping, differential settlement, and liquefaction (but to a lesser degree than at a liquefiable site). **Firm -** Subsurface is consolidated so nonlinear effects are not expected, but there may be significant soil amplification at the site. **Very Firm** - Very well consolidated soil or rock site. Soil amplification not expected although high frequency content of the earthquake may be observed at the site.
AE	**SITE_COMMENT**	The site commentary may contain the following information. 1. Site Grading Plan: If it is available, indicate drawing number. This should show contours of the undisturbed site and the final site elevation. For an isolated failure located in the center of other undamaged equipment this data may not be necessary. The grading plan should be obtained if damaged equipment is at the edge of a group of equipment, if there is extensive damage, or if there is any indication that soil/site conditions may have influenced failures. 2. Site Layout (arrangement) Diagram: If it is available, indicate drawing number. This diagram should show the location of all equipment on the site as well as bus locations. Both top and side views, if available, should be included. It would be desirable for this to show all equipment at the site including TR, CT, CVT, LA, WT, etc. (It would appear that there is no standard nomenclature for this diagram. In some cases there may be several related diagrams including a foundation diagram, construction diagram, electrical layout diagram, etc.) If there is an isolated failure, this diagram may not be necessary but bus connections to the damaged equipment must be known. 3. One Line Electrical Drawing: If it is available, indicate drawing number. This

		diagram should show a simplified view of the circuits at the site and would be used to explain the impact of damage on operations. This diagram would have a single line representing the circuits for the three phases. (It would appear that there is no standard nomenclature for this diagram.) 4. Operating Diagram: If it is available, indicate drawing number. This should indicate all equipment at the site including TR, CT, CVT, LA, WT, etc. (It would appear that there is no standard nomenclature for this diagram.) This diagram or computer database should be used to identify all equipment (included in this study) at the site to determine relative performance (% of equipment of a give type that is damaged) and identify equipment that is undamaged. It is important to get details on each type of equipment. 5. Geotechnical Report for Site Available: If it is available, indicate drawing number. 6. Comment on site characteristics (Summary of key information on site characteristics. Information such as layers of material, their depth and velocity of sound in each at site, cone penetration test data, site preparation, etc.) Reference drawing no. for location of control house used to determine map coordinates.
AF	**GRND_MOTION**	Ground Motion Commentary This section describes the character of the ground motion at the site. In most cases it will be derived from information obtained from personnel at the site during the earthquake. Comments on ground motion should fall into three types of comments: 1. Comments about how the ground motion was perceived by operating personnel at site during earthquake, 2. Comments of personal observation made by operating personnel at site during and immediately after the earthquake related to nonstructural response such as objects falling off of desks, books from shelves, movement of furniture, damage to "T" bar ceilings, superficial cracks in paint, etc., 3. Geotechnical effects observed at or near the site to include faulting, subsidence, liquefaction, ground deformations, landslides, differential settlements, gaps in soil around equipment footings, etc. If there is a strong motion record at the site the following data should be provided: 1. Coordinates of site instrument if different from site: latitude and longitude (degrees and decimal minutes to .001). See comments about resolution and accuracy under Epicenter Coordinates in earthquake data section. 2. Strong Motion Record "Near" Site (The definition of "near" should be based on likely similarity of the record to the ground motion at the site. This would be related to epicentral distance and more importantly local site conditions at the instrument site and the equipment site. In general, distances over a km away should be suspect.) 3. Coordinates of instrument "near" site. Latitude and Longitude (Degrees and decimal Minute to .001). 4. Peak Horizontal Acceleration: g 5. Peak Horizontal Velocity: in./sec. 6. Duration: 5% duration (Time interval (sec) where the record first goes above .05g to the last time that it exceeds this value.) and 10% duration (Time interval (sec) where the record first goes above .10g to the last time that it exceeds this value.).
AG	**DAMAGE_PAR_1**	Damage Parameter 1 would be the CAV if there is a strong motion record associated with the site.

AH	**DAMAGE_PAR_2**	Damage Parameter 2 would be another parameter derived from the ground motion record.
AI	**RESTORATION**	**Restoration Commentary** 1. Restoration Time (Total time to restore operation of site. See comments below.) 2. Cost of Damage (Cost should be broken down in to direct damage, manpower for restoration, and secondary costs to the utility such as replacement power or penalties associated with contracts for uninterrupted power.) 3. Spares needed to complete restoration 4. Equipment needed to complete restoration 5. Was Station Power Lost (What was source, impact, duration of disruption, method of restoration.) 6. Comments on Restoration - If there is much damage at the site, only aggregate restoration information will probably be available. Since many sites will contain transmission and distribution facilities, it would be desirable to get estimates of the restoration effort devoted to each. • Information sought would include total hours of work, total number of days, the time to restore operation of specific circuits (it is important to note if a given circuit was considered important or if it was of less importance so that it was not restored as fast as it might have been). • Critical path equipment items should be noted such as restoring operation of a given transformer or circuit breaker. A distinction should be made between restoring service under emergency conditions and complete restoration at the site. Spare parts or equipment items that were critical path items for the restoration of particular damaged equipment are noted . Examples might be obtaining spare bushings, ceramic members or gaskets for CB or TR, the availability of heavy moving equipment, the availability of specialized test or service equipment such as power factor test equipment to evaluate TR damage or equipment needed to treat transformer oil. • Problems with communications are noted. This would include damage to communications equipment and problems associated with saturation. • The views of the station manager as to what he thought would have improved the restoration process. Because of the need to properly interpret information associated with the restoration process, specific data fields such as man-days of effort or time to restore a circuit or facility are not given.
AJ	**IMPACT_DAMAGE**	Impact of Damage Commentary 1. Describe the disruption at the facility resulting from the equipment damage. 2. Describe the disruption to the system resulting from the equipment damage and operation of the site.

A.5 Equipment Data Fields (columns AK through BN)

Equipment that has experienced earthquake damage and equipment that has performed well after significant earthquake excitation are included in this database. For simplicity in searches of the database, preferred names used in fields are shown in **bold** letters. In general, field contents would be limited to one of these choices.

A.5.1 Notes

1. In general, if a phase has a separate piece of equipment associated with it, such as one phase of a circuit breaker, it will be considered as a separate item of equipment. It should be emphasized that this is not the way the industry looks at equipment. A transformer bank or circuit breaker consisting of three single-phase transformers or circuit breakers would be considered as three pieces of equipment while a three-phase transformer or circuit breaker would be considered as a single piece of equipment.

2. In general each piece of equipment will have a record associated with it. The exception would be for success data. For example, three circuit breakers (9 equipment items) that were installed in an identical fashion would be described in a single record. In general, this cannot be done for damaged equipment as each item may have different damage.

Col.	Field Name	Description
AK	**EQP_STATUS**	The standardized values are: **Damaged, Undamaged**
AL	**SECOND_DMG**	**Yes, No** Secondary damage indicates an item of equipment is damaged as a result of damage to another equipment item. Secondary damage should not be considered in determining the fragility of a class of equipment. A conservative approach should be taken and this class should only be used if it is clearly demonstrated that there was an interaction problem. For example, at Los Banos in the Morgan Hill earthquake, the two 500 kV CBs that had failed interrupter head support columns were adjacent to current transformers that were flexible perhaps indicating that the columns were pulled by the CTs. However, guys were damaged on heads that were not adjacent to CTs. Thus, it is assumed that the CB damage is <u>not</u> Secondary Damage. Likewise, at Metcalf Substation in the Loma Prieta earthquake, some disconnect switches were damaged that were connected to equipment that did not fail, so that <u>no</u> failures will be classed as secondary damage.
AM	**NO_ITEMS**	Indicates the number of identical equipment items represented by the record. Most often this will be 1 for damaged equipment as the description of damage would be different for each item. A single record could be used for undamaged equipment. It is important that "identical" equipment that is grouped together is installed in the same way. Often, bus connections for different phases will be different. These should be assumed to be the same unless there is evidence that the difference has a seismic impact.

AN	**TYPE_EQP**	**Type of Equipment** The standardized values are: **Aircore Reactors - AR** **Batteries - B** **Capacitor Racks - CR** **Circuit Breaker - CB** **Circuit Switcher - CS** **Communications - CM** **Coupling Capacitor Voltage Transformer - CVT** (Note that these devices are referred to by several names, i.e., CCVT, CCPD) **Current Transformer - CT** **Disconnect Switch - DS** **Lightning Arrester - LA** **Motor Operated Disconnect Switch - MODS** **Potential Transformer - PT** **Post Insulator - PI** Post insulators are used in several types of equipment (WT, DS. AR, etc.) and their failure in those applications is included with that equipment. Post insulators used for other applications, such as bus supports, should be included here. **Reactors - R** **Station Power - SP** **Transformer - TR** **Wave (**or line**) Trap - WT** Several types of equipment (at a given operating voltage) have major distinctions that impact their seismic performance or serve to define the equipment subtype. The subtypes for each type of equipment are defined below. The emphasis for the definition of subtypes is on factors that influence seismic performance. For this reason, it is important that subtype information is entered into the database. In addition there may be other, more subtle distinctions that impact equipment performance. This is discussed under Eqp_Comment.
AO	**CB_SUBCLAS**	**Circuit Breaker Subclass:** The standardized values are: **Live Tank, Live Tank Seismic Qualified, Dead Tank, Dead Tank Seismic Qualified.** The Equipment Commentary should note if CB is gas insulated, or has an integral current transformer: Circuit breakers are assumed to be single phase unless stated otherwise. NOTE that there is a need to identify, and assign a designation to several types of 500 kV GE ATB CBs and to 230 kV GE ATBs. This is done in the following way. At the 500 kV level, there is not much damage to this equipment, but various units look different and they probably have different seismic strengths. It would be desirable to keep them separate in the database so that it can be updated later. Note that CBs may have different BILs and therefore the length of interrupter head support columns may be different.
AP	**TR_SUBCLAS**	**Transformer Subclass:** The standardized values are**:** **Large Rad/Man. -** large radiator with central manifold **Large Rad/O Man. -** large radiator without central manifold (The size of a radiator is judged by the relative weight per connection to TR. If the horizontal cross section of a radiator is larger than 1 foot by 4 feet per pipe support define it as **Large**.) **Med. Rad/Man. -** medium radiator with central manifold **Med. Rad/O Man. -** medium radiator without central manifold **Small Rad. -** small radiator One of the most frequent types of damage to transformers is leaking radiators, and this is associated with radiator size and if radiator segments are connected to the transformer tank directly or if they are first connected to a central manifold that is then connected to the tank. Flexibly mounted radiators are the most vulnerable.

		The method of TR cooling can effect radiator size, and this can be noted in Equipment Commentary. Cooling and other parameters follow: self-cooled (SC) oil/air (OA) forced air (FA) forced oil (FO) load-tap-changing. TRs are assumed to be core type unless shell type is noted. Radiator dimensions and bracing, if any, should be described for large radiator TRs, single-phase, and three-phase.
AQ	**TR_BUSHING**	**Transformer Bushings:** The standardized values are **Porcelain, Composite** In Equipment Commentary note other information such as manufacturer and model
AR	**LA_SUBCLAS**	**Lightning Arrester Subclass:** The standardized values are: **Free Standing, TR Mounted**. In Equipment Commentary note other information such as throat diameter.
AS	**WT_SUBCLAS**	**Wave (or line) Trap Subclass**: The standardized values are: **Horizontally Mounted, Vertically Mounted, or Vertically Suspended**. The Equipment Commentary should note rating of post insulator supports.
AT	**CVT_SUBCLAS**	**Coupling Capacitor Voltage Transformer Subclass**: The standardized values are: **Post Mounted** and **Suspended**.
AU	**PT_SUBCLAS**	**Potential Transformer Subclass**: none defined
AV	**CT_SUBCLAS**	**Current Transformer Subclass**: none defined
AW	**DS_SUBCLAS**	**Disconnect Switch Subclass:** The pre-selected values are**: Horizontal Swing, Vertical Swing, or Pantographic**. Indicate in the Equipment Commentary the type, mounted on bus structure or independent support. Even though the failure of these devices is usually in the porcelain members, which are post insulators, their failure will be noted separately.
AX	**MODS_SUBCL**	**Motor Operated Disconnect Switch Subclass**: none defined
AY	**DISPATCH_D**	**Designation** (Dispatch) Usually a coded number used at the substation to indicate bank, position, type of equipment, and north/south or east/west, i.e., 805 or Bank A)
AZ	**OPERATING_V**	**Operating Voltage** (primary for TR)**:** The standardized values are: **500, 345, 230, 138, 115, 60, 34, 12, 4**. Kilovolts are assumed. (A system may be 220 but 230 would be used as critical dimensions are almost the same.)
BA	**SECONDARY_V**	**Secondary Voltage** (for TR): The standardized values are: **345, 230, 138, 115, 60, 34, 12, 4**
BB	**CURRENT_RATE**	**Current Rating** (operating current) (MVA for TRs, interrupting for CBs)
BC	**BIL**	**Basic Insulation Level:** This may influence the length of porcelain members. Note, for example, that two post insulators can be the same length but have different BILs due to the design of their sheds (Sheds with higher BIL may add weight to the insulator), however, for the same general design, a higher BIL will dictate a longer insulator. Both of these factors would increase seismically-induced inertia loads and degrade seismic performance for a unit with the same cantilever strength. In general, all power equipment will be for a given BIL than can vary between different companies. For example, two live tank CBs may have different length interrupter head support columns. Note that seismic performance will be influenced by operating voltage, BIL, and cantilever strength, but a lack of information for much of the data that is collected makes a rational analysis very difficult.
BD	**CANTILEVER**	**Cantilever Strength** A critical parameter in seismic performance. This data many may not be available. It is probably reasonable and conservative to assume that typically lower values for cantilever strength be used. The cantilever strength should be expressed in pounds. (*1500*)
BE	**MANUFACTUR**	Manufacturer name
BF	**MODEL_DES**	Manufacturer model number or designation
BG	**YEAR_MANUF**	Year manufactured

BH	**UWG_CLASS**	**Utitlities Working Group Class -** These are standardized classes defined by the Utilities Working Group
BI	**WEIGHT**	**Fully Dressed Weight** The total weight should be expressed in pounds. For transformers, if component weights are available, they should be noted in the Equipment Commentary.
BJ	**EQP_COMMENT**	**Equipment Commentary** (see below)
BK	**EQP_INSTAL**	**Equipment Installation Commentary** (see below)
BL	**EQP_DAMAGE**	**Equipment Damage Commentary** (see below)
BM	**RESTORATION**	**Restoration Commentary** In general, information on the restoration time for a given equipment item will not be available unless it was one of just a few items that failed at the facility. Unless this is the case, the substation database will not deal with restoration issues. The exception will be if the equipment item was significant in determining the restoration of the substation. Examples might be a CB or TR that had to be repaired and spare parts were not available, the equipment had to be replaced, or special equipment needed for the repair was not available. The emphasis is on gathering information that would be useful for planning for future earthquakes. Delays due to the need to get spares, replacement equipment or special maintenance equipment should be noted. Any suggestions that the station manager or maintenance personnel can make that would improve seismic performance of the equipment or the post earthquake response should be sought and noted.
BN	**FAIL_MODE**	**Potential Failure Modes** (see below)

Equipment Commentary

The following subclasses do not have fields in the database and should be entered in the equipment commentary field.

- **CR Subclass** (Capacitor Racks): These are usually unique structures.
- **PI Subclass** (Post Insulator): The pre-selected values are: **Solid, Station, Pin&Cap**
- **AR Subclass** (Aircore Reactors**)**: These are usually unique structures.
- **R Subclass** (Reactors): These are usually unique structures; however, they may be similar to transformers.
- **SR Subclass** (Synchronous Reactors): Large motor-like devices.
- **CM Subclass** (Communications)**:** rack mounted with or without top support.
- **B Subclass** (Station Batteries)**:** number of tiers in rack, anchorage, rack bracing, battery side restrains, battery end restraints, spacers.
- **SP Subclass** (Station Power): Source(s) of supply, KVA

Other Relevant Data (It is important to adequately identify equipment. It would appear that for some subtypes of equipment the model number and typical name plate data such as operating voltage, current rating, etc. does not adequately define the item. Equipment can look identical and yet be significantly different seismically. It is desirable to determine the length of ceramic members and the weight of that part of the equipment that is supported by ceramic members, type of operating mechanism, etc.)

Equipment Seismic Specifications (in effect at the time of purchase)
Method of Qualifications (test or analysis)
Seismic Modifications to Equipment (if yes, indicate character of modification)
Site Seismic Specifications (specifications in effect at the time of construction, indicate character, i.e., static, dynamic, g level)

Mechanical drawings available for the equipment?
Outline Drawings for the Equipment - If it is available, indicate drawing number.
Seismic Outline Drawings Available for equipment? (LADWP have these drawings for some equipment, but generally not available). These drawings give the weight of the equipment, the center of gravity, natural frequencies, anchorage loads associated with each frequency)

Additional details about equipment should be noted. For example, for circuit breakers note the presence of CT; for transformers note component weight. Cooling and other parameters follow: self-cooled (SC), oil/air (OA), forced air (FA), forced oil (FO), and load-tap-changing. TR are assumed to be core type unless shell type noted. Radiator dimensions and bracing, if any, should be described for large radiator TRs; for lightning arresters note throat diameter and types of design; for wave traps note cantilever strength of post insulator supports.

Equipment Function (Identify if the equipment served some special function, i.e., spare CB on double bus, sectioning on segmented bus, TR with tertiary winding for station power.)

Equipment Installation Commentary

Because of the variation in installation practices, installation descriptions will tend to be text rather than key works. The following topics should be addressed.

- Equipment Anchorage (For equipment on support structures, this would describe how the equipment is anchored to the support structure. Indicate if it is welded, bolted, friction clip, other. For pad mounted equipment it would describe the anchorage. For equipment anchored to pads, see Support Structure Anchorage below.
- Comment on Equipment Anchorage (Note any special observations or conditions.)
- Support Structure, manufacture supplied or custom
- Support Structure Plans Available. File, no, yes (drawing number)
- Comments on Support Structure. Describe those features of the support structure that might influence the dynamic response of the equipment. For example, slotted bolt holes, flexibility that might significantly lower the natural frequency of the supported equipment, etc.
- Support Structure Anchorage. Indicate the type of anchorage: cast in place bolts, grouted in place bolts**,** weld to embedment , expansion bolts, friction clips, welded friction clips.
- Standard Anchorage Details Available. File, no, yes (drawing number)
- Comments on Support Structure Anchorage (Note any special observations or conditions.)
- Foundation. Slab, separate footings, piles,
- Standard Foundation Details Available. File, no, yes (drawing number)
- Comments on Foundation (Note any special observations or conditions.)
- Type of Power Connections - Rigid, flexible
- Type of Control Connections - Does the equipment have intra and inter equipment connections.
- Comments on Connections - On bus connections note flexibility of connection and how much connection point displacement can be accommodated (both longitudinal and transverse) and if it appears to be adequate for relative deflections. Make same observation for control connections including electrical, pneumatic and hydraulic connections if they are present.

Equipment Damage Commentary

Description of Damage - (Specific equipment damage should be noted. Photographs taken at the time of the earthquake or recent pictures should be included so that character of the damage can be conveyed at a meeting. Long, detailed written descriptions are not necessary at this point, although, they may be included if they are from the original damage reports. Examples of damage are blown gaskets and their location, cracked or chipped ceramic, destroyed ceramic member, distress in the support structure to include working of connections, deformation of members, chipped or cracked paint, distress in the anchorage to include failed bolts or welds, stretched bolts, play in the anchorage, deformation in the structure around the anchorage, etc. If some types of failure are observed on different equipment items, each should be assigned a code and this should be indicated on the site layout diagram.)

The description of damage should also include signs of distress. Signs of distress would include cracked or chipped paint, motion in slotted holes, and deformation of materials. Damage would be breaking or tearing of materials or deformations that might impair the operation of the equipment.

- Ceramic Damage - This would include broken ceramic members or damage to the gasket at the interface with the failed ceramic.
- Gaskets - limited to blown and leaking gaskets. Note details of situation, such as which gaskets are blown and side on which the gasket blew.
- Bus Connection - Deformation or broken bus connection.
- Equipment Anchorage Damage - Note distress as well as damage. Distress might be cracked paint, stretched bolts, sliding of equipment, bent anchor lugs on equipment, bending of materials near the anchorage. Damage might include broken bolts, rotated friction clips, equipment coming free of anchorage, broken anchor lugs, broken welds, torn metal near the anchorage.
- Support Structure Damage - Look for deformations in the primary load path, particularly near anchor points, signs of motion at bolted connections, particularly those with slotted holes.
- Support Structure Anchorage Damage - See Equipment Anchorage Damage.
- Foundation Damage - Look for differential settlements or motion of footings, slabs that are out of level, gap in fill around the edge of the slab or footing, spalling or cracking of concrete near anchorage.
- Other Equipment Damage - Note any other damage to equipment such as leaking radiators for transformers, damage to pressure boundary to the air or gas system (other than gasket damage), secondary damage to equipment due to being hit by other objects, etc.

Damage Pictures Available - File, no, yes (identification)

Factors contributing to the failure should be listed. (Attempt to give a complete list and identify the most likely.(i.e., damaged ceramic support column and interaction due to lack of slack, inertial loads, nonlinear action due to slacked in bracing member, nonlinear action due to impacting, motion of bus support, etc.) Additional factors might be the use of a higher than normal BIL, the use of high strength porcelain, flexible support structure, or amplification in support structure.

Potential Failure Modes

Failure modes of different types of equipment are identified and coded below. This list may expand as new failure modes of uncovered. This should be expanded as additional failure modes are identified.

Circuit Breaker (Dead Tank)- **CB:**

- **lhg** - leaking head gaskets
- **lscg** - leaking support column gaskets
- **dscp** - damaged support column porcelain
- **das** - damaged air supply
- **a** - inadequate anchorage
- **fbc** - failed bus connections
- **o** - other

Transformer - **TR:**

- **spr** - sudden pressure relay
- **lbs** - leaking bushing seal
- **lbts** - leaking bushing-tank seal
- **lrsf** - leaking radiator support flange-tank seal
- **cb** - cracked bushing
- **if** - internal fault
- **fbc** - failed bus connection
- **o** - other

Lightning Arrester - **LA:**

- **fp** - failed porcelain
- **fbc** - failed bus connection
- **o** - other

Wave (or line) Trap - **WT:**

- **fp** - failed porcelain
- **ir** - inadequate restraint (for suspended WT)
- **fbc** - failed bus connection.

Coupling Capacitor Voltage Transformer - **CVT:**

- **fp** - failed porcelain
- **ol** - oil leak
- **fbc** - failed bus connection.
- **o** - other

Potential Transformer - **PT:**

- **fp** - failed porcelain
- **ol** - oil leak
- **fbc** - failed bus connection.
- **o** - other

Current Transformer - **CT:**

- **fp** - failed porcelain
- **ol** - oil leak
- **fbc** - failed bus connection.
- **o** - other

Disconnect Switch - **DS:**

- **fp** - failed porcelain
- **dom** - damage operating mechanism
- **ma** - misalignment
- **fbc** - failed bus connection.
- **o** - other

Capacitor Racks - **CR:**

- **dss** - damaged support structure
- **ica** - inadequate component anchorage
- **fbc** - failed bus connection
- **a** - anchorage
- **o** - other

Aircore Reactors **- AR:**

- **dss** - damaged support structure
- **fbc** - failed bus connection
- **a** - anchorage
- **o** - other

Reactors **- R:**

- **lbs** - leaking bushing seal
- **if** - internal fault

lbts - leaking bushing-tank seal
lrsf - leaking radiator support flange-tank seal
cb - cracked bushing
fbc - failed bus connections
o - other

Synchronous Reactors - **SR**:
db - damaged bearings
gl - gas leak
a - anchorage
o - other

Communications - **CM:**
dec - damage electrical connect
a - anchorage
o - other

Station Batteries - **B:**
dcc - damage cell case
db - damage bus
sa - spilled acid
dec - damage electrical connection
dss - damaged support structure
ica - inadequate cell anchorage
a - anchorage
o - other

Station Power - **SP**:
dbc - damage bus connection
a - anchorage
dec - damaged electrical connection
o other

Impact of Damage

Comments of Impact of Damage (In general, damage to a given equipment item will not be directly related to the impact on the operation of the facility or the system. If facility or system performance can be attributed to a specific equipment item, it should be noted.)

Substation Equipment Preference Summary Sheet

The summary of equipment performance should be organized by operating voltage (starting at highest voltage). For each type of equipment and subclass, the number of items, where each phase is considered as a separate item (three phase transformers and circuit breakers are considered as single items), which remained functional or was nonfunctional should be indicated. Damage should be deaggregated. The total number of failures may exceed the number of items that malfunctions. For example, on an air blast circuit breaker, one phase may have had blown head gaskets, broken support columns, and damaged air supply.

Voltage: 500 kV__, 345 kV __, 230/220 kV__, 110 kV__

Transformers: __ OK, __ Not OK:
__ Bushing gasket leak, __Cracked Bushing, __Bushing/TR gasket leak,
__Radiator leak, __ LA failure, __ damage anchorage, __other

Live Tank Circuit Breakers: __ OK, __ Not OK
__ Blown head gasket, __ Blown support column gasket, __ Damage support column,
__ Damage air supply, __ Damage anchorage, __ other.

CVT: __ OK, __ Not OK
__ Leaking, __ Damaged porcelain, __ other

Air Disconnect Switches - Mounted on bus support structure: __ OK, __ Not OK
__ Miss-aligned, __ Damage porcelain, __ Damage operating mechanism, __ Other

Air Disconnect Switches - Independent support structure: __ OK, __ Not OK
__ Miss-aligned, __ Damage porcelain, __ Damage operating mechanism, __ Other

Current Transformers: __ OK, __ Not OK
__ Leaking, __ Damage porcelain, __ Other

Voltage: 500 kV__, 345 kV __, 230/220 kV__, 110 kV__

Transformers: __ OK, __ Not OK:
__ Bushing gasket leak, __Cracked Bushing, __Bushing/TR gasket leak,
__Radiator leak, __ LA failure, __ damage anchorage, __other

Live Tank Circuit Breakers: __ OK, __ Not OK
__ Blown head gasket, __ Blown support column gasket, __ Damage support column,
__ Damage air supply, __ Damage anchorage, __ other.

CVT: __ OK, __ Not OK
__ Leaking, __ Damaged porcelain, __ other

Air Disconnect Switches - Mounted on bus support structure: __ OK, __ Not OK
__ Miss-aligned, __ Damage porcelain, __ Damage operating mechanism, __ Other

Air Disconnect Switches - Independent support structure: __ OK, __ Not OK
__ Miss-aligned, __ Damage porcelain, __ Damage operating mechanism, __ Other

Current Transformers: __ OK, __ Not OK
__ Leaking, __ Damage porcelain, __ Other