SCALE in STEAM TRANSMISSION LINES at THE KAMOJANG GEOTHERMAL FIELD

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Kamojang Geothermal Field has been supplying steam for the 140 MWe Power Plant since 1982. Although this field produces only saturated steam with no water, scale build up has been observed at places near the wellheads. Detailed investigations during the last two years have distinguished the sources of this scale and enabled different treatments for each case.

1. INTRODUCTION

Kamojang Geothermal Field is located in West Java, INDONESIA, about 40 km Southeast of Bandung, the Capital City of the West Java Province, at an altitude between thirteen and fifteen hundred meters above sea level. This geothermal field is categorized as a vapour dominated field where production from all geothermal wells is dry saturated steam. Wells located in the center of the field usually produce dry steam and some of them produce slightly superheated steam, while wells drilled in places around the perimeter of the field produce slightly wet steam. This field has been used to supply steam for the 30 MWe turbo generator since 1982 and for the 110 MWe one in 1986, making the total capacity of the geothermal power plant to 140 MWe. Steam from 24 to 26 production wells are delivered to the power plant through four separate steam transmission lines: PL401, PL402, PIA03 and PL404.

The power plant is usually shut down one month each year for maintenance. During this time, some production wells were retested for their production and some of them were kept on bleed. For the first three years, there were no problems encountered in steamfield and power plant options. But in 1985, it was found that the 30 MWe turbine had been consuming steam more than it had previously. So, later that year, the turbine was dismantled and it was found that silica scale had built up at the first stage 30 MWe turbine blades and nozzles. It was suspected that the quality of steam entering the power plant had changed, so the production wells were retested. But, the test results were negative, there were no changes in steam quality. During the following power plant maintenance period, sections of steam transmission pipeline were dismantled, from the wellhead to the main steam transmission line. It was found that scale had built up on the pipe walls, especially at locations from four to eight meters distance from the wellhead and downstream of pipe connections where the direction of steam flow changed.

2. OCCURRENCE OF SCALE

Since Kamojang is a vapour dominated field, there has been no need to install production separators and steam that is produced from production wells can be fed directly into the steam turbine, through the four steam transmission lines. Figure 1 shows a schematic diagram about the arrangements of the pipelines and the production wells connected to each of them.

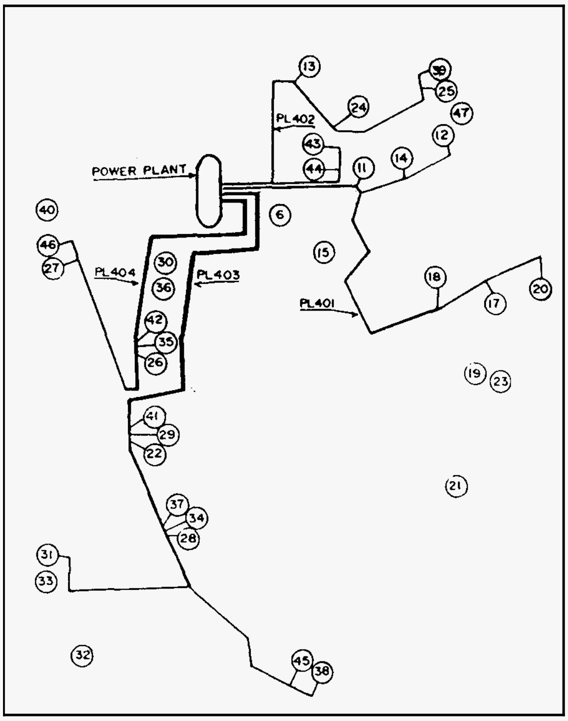

Figure 1: Steam Transmission Lines

Initially all production wells produced dry saturated steam, but later on, some of them produced slightly superheated steam while some of them produced slightly wet steam. Since the transmission lines have already been utilized, it was not possible to group the wells according to their precise characteristics into each steam transmission line. Table 1 lists the degrees of superheat (measured in 1989) and the initial production test data from all production wells.

Table 1. Initial production and Degrees of superheat in 25-cm diameter steam lines.

Pipeline System	Well #	Ini.Prod. (ton/H)	Degrees of Superheat
PL401	11	80	4.9
	12	20	none
	14	60	4.5
	17	60	4.1
	18	107	4.1
	20	17	none
PL402	24	38	2.4
	25	20	10.7
	39	15	2.5
	43	16	7.2
	44	45	10.1
PL403	22	80	7.1
	28	30	4.3
	31	37	1.3
	34	42	3.8
	37	65	wet
	38	36	4.2
	41	71	wet
	45	39	1.9
PL404	26	66	5.6
	27	80	wet
	30	26	6.7
	35	27	4.8
	36	122	10.2
	42	70	3.8
	46	45	3.9

The PL401 steam transmission line carries steam from six wells with different characteristics, from just saturated steam (KMJ12 & KMJ20) to 4.9 degrees of superheated steam (KMJ11). When sections of this line, from the 25-cm pipe at the wellhead to the intersections at the 50-cm or 80-cm line, were dismantled every year since 1986, it was found that scale had built up at the 25-cm pipe walls at a distance from four to eight meters from the wellhead. Suwana and Notowidagdo (1992) mentioned that the thickness of this scale varies from one or two millimeters up to two centimeters. Usually this scale started to occur at locations where there was a change in flow direction, and the thickness decreases along the direction of the flow. From inspections carried out through 'manholes' at the 50-, 70- and 80-cm main steam transmission lines, there was no scale built up along the inside of these pipes, except a uniform thin layer of grayish-white deposit.

Figure 2 shows a 25-cm pipe section at well KMJ18 (photographed in the 1991 maintenance period), at a distance of about 7 meters from the wellhead and after a change of steam flow direction, which is away from the camera. Figure 3 shows the scale specimen taken from well KMJ11 for chemical and mineralogical analysis.

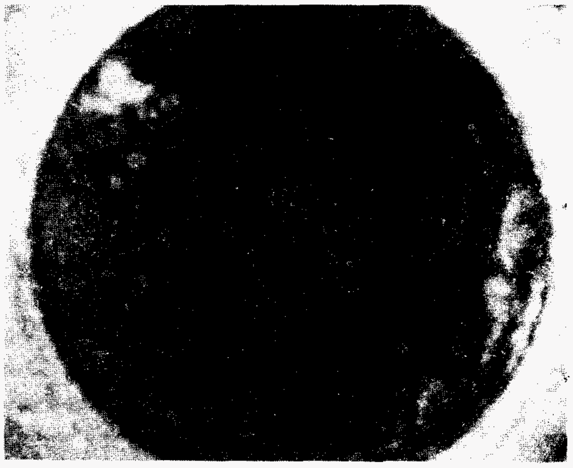

Figure 2: Scale in 25-cm diameter pipe of well KMJ18

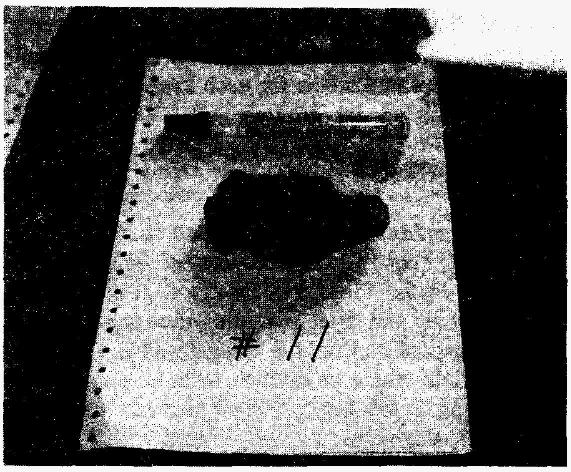

Figure 3: Scale specimen from well KMJ11

The PL402 steam transmission line is used to gather and deliver steam from five wells with 2.4 to 10.7 degrees of superheat. This pipeline has never been dismantled thoroughly but observations made from orifice plates and through 'manholes' at the 40- and 60-cm main transmission lines, have shown that there were no scale built up along the inside of the 25-, 40- and 60-cm pipes except a uniform thin layer of deposit, similar to the deposit observed in the PL401 main line. The PL403 steam transmission line is connected to eight production wells that discharged slightly wet steam (KMJ37 & KMJ41) to 7.1 degrees superheated steam (KMJ22). It was noted in 1991 that steam production from well KMJ41 had been decreasing substantially. So, during the maintenance period that year, sections of pipes were dismantled, beginning from the wellhead of KMJ41 and ending at the intersection to the 80-cm pipe. It was found that scale had built up inside the 35-cm pipe, starting at 10 meters away from the wellhead, which was rather thick in comparison to the scale in the PL401 steam line. It was also discovered that, physically, this scale was different from the one found in PL401. Figure 4 shows a photograph of this scale (taken in 1992) in a 35-cm pipe section at a distance of 20 meters from the wellhead; the direction of the steam flow is towards the camera.

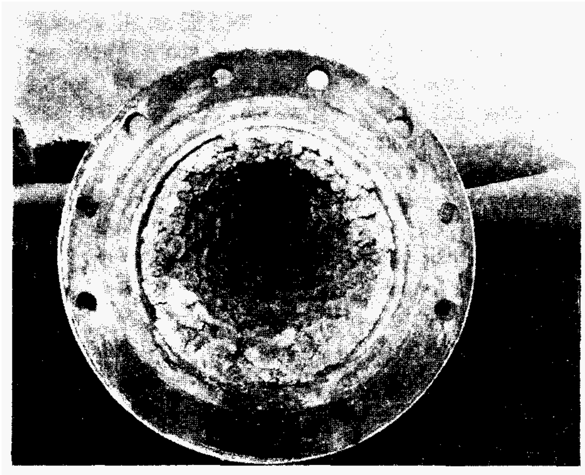

Figure 4: Scale in 35-cm diameter pipe of well KMJ41

The PL404 line is used to deliver steam from seven production wells with varying conditions, from slightly wet *steam* (KMJ27) to 10.2 degrees superheated steam (KMJ36). The 60- and 80-cm main steam transmission lines have never been dismantled except the section of 25-cm and 50-cm steam lines from well KMJ27 (in 1991). It was found that scale built up at that section of pipe was enormous, reducing the effective area of that particular pipe section to only 25%. Suwana and Soeraswo (1993) later found that this scale was similar to the scale deposited in the 35-cm steam line at well KMJ41. Figure 5 shows a photograph of scale in a 50-cm pipe section at well KMJ27 (taken in 1991), at a distance about 10 meters from the wellhead; the direction of the steam flow is away from the camera.

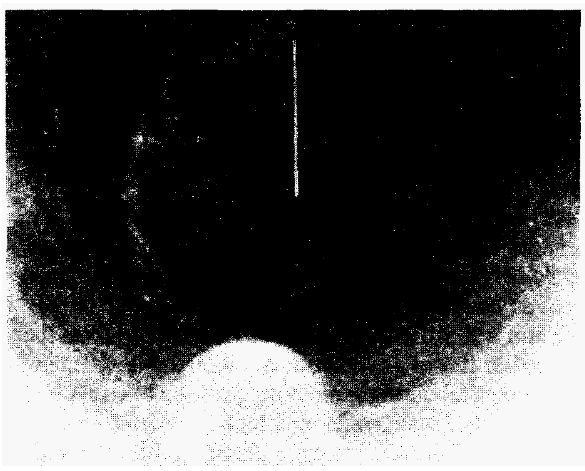

Figure 5: Scale in 50-cm diameter pipe of well KMJ27

3. DISCUSSION

3.1. Types of scale

During the 1991, 1992 and the 1993 power plant maintenance periods, some scale samples had been collected from sections of discharged pipes (25 to 50 cm diameters) from wells KMJ11, KMJ18, KMJ27 and KMJ41 for chemical and mineralogical analysis. Figure 6 shows a schematic diagram of that discharge pipe from the wellhead to the main steam transmission line and the locations (denoted by well numbers) where those samples were taken.

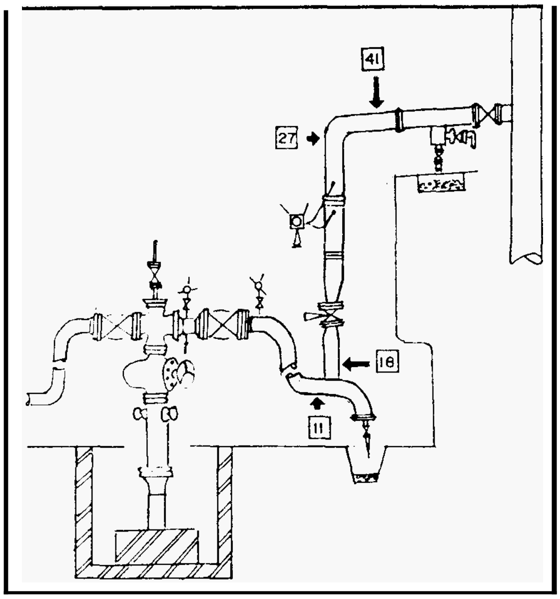

Figure 6: Schematic diagram of wellhead pipe arrangement

At the beginning, it was thought that all scales in Kamojang should be similar since all geothermal wells are only producing *dry* steam without any water. However, observations made during the past two years have shown that Kamojang Geothermal Field has at least two types of scale with different physical characteristics.

The first type of scale is found in wells that discharged *dry* saturated steam and/or superheated ***steam,*** at places between the wellhead and the main steam transmission line. Usually it started to occur at places where there is a sudden change in flow direction, such as downstream of a T-connection. It is also found downstream of an intersection into the main steam transmission lines. From the first occurrence of this scale, its thickness decreases along the direction of the flow. This type of scale is very hard, compact, strongly attached to the pipe walls and has a uniform size with a clean grayish white colour (see Figures 3 and 4). Since the wells are only producing *dry* saturated steam and/or superheated steam, then this scale must have originated from dissolved species in the vapour phase. This scale is thought to have originated from the silica dissolved in steam. The concentration of silica in steam is very low; James (1986) calculated that the silica concentration in steam = 0.15 ppm. However, the steam flow from the well is quite high (80 ton/H or more) and no wellhead separators are being used, *so* it is reasonable that the scale inside the 25-cm pipe can reach a thickness of about one to two centimeters per year.

The second type of scale is found only in wells that discharged slightly wet steam, at locations between the wellhead and the intersection to the main steam transmission line where there is a change in direction and/or a change in velocity of the flow. In a straight line portion of the pipe, the thickness of this type of scale increases along the direction of the flow to a certain location. Then the scale begins to decrease as the flow approaches an intersection into the main steam transmission line. This scale is rather soft, loosely attached to each other, has uneven forms and a dirty grayish-white colour (see Figures 4 and 5). At specific places, such as downstream of a connection at the 50-cm pipe from well **KMJ27** or almost at the end of a **35-cm** pipe from well **KMJ41,** this scale can almost fill the diameter of the pipe which will then restrict the amount of flow.

3.2. Chemistry of scale

Although scale samples are abundant it was not possible to perform a wide variety of analysis for evaluating the chemical properties of these scales. Table 2 lists the results of wet chemical analysis for four scale samples, two scale samples collected from superheated wells **(KMJ11 & KMJ18)** and two collected from wet-steam wells **(KMJ27 & KMJ41)**. Table 3 describes the mineralogical results found by X-Ray Diffraction Analyses of those samples.

Table 2. Chemical analysis of scale samples (in percent by weight)

CONST.	KMJ11	KMJ18	KMJ27	KMJ41
SiO_2	89.38	89.18	88.47	88.57
Al_2O_3	2.05	5.00	3.63	4.57
FeO	0.46	0.23	0.46	0.93
Fe_2O_3	2.00	0.81	2.00	1.33
CaO	0.36	0.36	0.55	0.36
MgO	0.22	0.25	0.22	0.43
Na_2O	0.84	1.41	1.38	1.08
K_2O	0.03	0.17	0.06	0.07
$Ti0_2$	0.01	0.02	0.02	0.01
MnO	0.02	0.01	0.01	0.02
P_2O_5	0.02	0.08	0.02	0.04
SO_3				
S total				
CO_2	0.02	0.02	0.05	0.04
H_2O^-	1.33	0.64	1.25	0.39
H_20^+	0.54	0.23	0.29	0.48
LOI	4.22	2.25	3.04	2.38
Sr(ppm)	80	137	110	223
Ba(ppm)	878	301	253	878
Zr(ppm)				
TOTAL	97.28	96.40	98.41	98.41

Table 3. Results of XRD Analyses

ORIGIN	MINERALS
KMJ11	Quartz, Pyrophyllite, Gypsum
KMJ18	Quartz, Alunite
KMJ27	Calcite
KMJ41	Quartz, Haematite, Wairakite

Wet chemical analyses confii that silica is the major constituent in all samples **(88.5** to **89.5%)** so all samples could be classified into a silica type scale. There are slight variations in the concentration of minor constituents but these variations do not give any indication to the origin of each scale.

The results of the XRD analyses are not quite satisfactory because they do not match with the wet chemical analysis. For instance, the XRD result from **KMJ27** indicates that calcite, instead of quartz, is present but the concentration of calcium oxide is very small (0.55%) in comparison with the silica concentration **(88.47%)** Also, the **XRD** result from well **KMJ11** shows that gypsum is present but the wet chemical analytical result does not indicate any SO_3 present.

3.3. Scale removal

When the silica scale was first discovered in **1986,** acids and bases were utilized as dissolving agents but without any success. Attempts were made to remove the scale mechanically, by using chisels and hammers. Since these scales were very hard and strongly attached to the pipe walls, as well as to each other, cleaning the scale mechanically requires excessive labour and time. While the available time was very limited, it was then decided to replace sections of pipe which had scale deposits with new sections of pipe, so the mechanical cleaning of the withdrawn pipes could be performed later. In **1989** a chemical cleaning solution was supplied by a local contractor after conducting several experiments. This solution is a mixture of phenol, trichlorethylene, sodium-metasilicate, foxmic-acid and alkyl benzene sulfonate with a trade name "Light Bold Super **103".** It was successfully used to remove scale in steam lines from wells **KMJll** and **KMJ18** by allowing the scale to dissolve in the solution. Time required to completely dissolve the scale varies from six to twenty-four hours, depending on the thickness of the scale.

When the second type of scale was discovered, the chemical cleaning solution was tested for dissolution, but the results were not satisfactory. Although this scale is not as hard as the previous type of scale, it is very thick and still difficult to remove mechanically from the pipe walls. It was found that combining the chemical and mechanical cleaning methods gave the best result in removing the scale. The combined method can be described as follows: pour the chemical into the pipe until all the scales are immersed in the solution, soak for **24** hours until the bonds between the scale and the pipewalls become loose, remove the large portion of the scale by using mechanical means and then use the chemical solution again to completely dissolve the scale on pipewalls.

4. CONCLUSIONS

There are two types of silica scales found in Kamojang Vapour Dominated Geothermal Field that have rather similar chemistry but different physical characteristics.

- First type scale

This scale is thought to be originated from the silica dissolved in steam. This scale exists in wells that produce dry saturated steam and/or superheated steam at places where a sudden change in the direction and velocity of the flow occurs, usually just a few meters from the wellhead. This scale is very hard, strongly attached to the pipe walls as well as to each other, has a uniform shape and a clean grayish-white colour. Its thickness decreases along the direction of the flow. This scale also exists downstream of intersections at the main steam transmission pipelines. Removal of this scale can be carried out chemically by using the mentioned chemical cleaning solution.

- Second type scale

The possible origin of this scale is the silica dissolved in water droplets which are carried along with the produced steam. This scale exists only in wells which produce slightly wet steam, at places where a gradual change in the direction and velocity of flow occurs. It is usually found in the straight portion of steam lines, beginning at about eight to ten meters from the wellhead and ending close to the intersections into the main steam transmission line. This scale is not very hard, loosely attached to each other, has irregular shapes and a dirty grayish-white colour. Its thickness increases along the flow direction until a certain position, then decreases as the flow approaches the intersection into the main steam transmission line. This type of scale does not exist inside the main steam transmission line. Scale removal can be carried out by a combination of chemical and mechanical methods.

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